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IRON AND STEEL ENGINEER

VOL. XII AUGUST • 1935 NO. VIII

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G. R. CARROLL

Electrical Superintendent, Jones & Laughlin Steel Corporation, Aliquippa, Pa., President of the Association of Iron and Steel Electrical Engineers for 1935-1936.

The President's Message

As the Twenty-Seventh President of the Association of Iron and Steel Electrical Engineers in officially assuming the honor that has been accorded me by the members of our society, I wish to take this opportunity for reviewing some of

the fundamentals responsible for the growth of our society. Motivated by the spirit of controversy, the very basis for the existance of our organization, we have grown from a small group of electrical engineers to one that includes on our roster every type of engineer and operating executive in the steel and allied industries.

By firmly embedding its roots, thereby lacking the vulnerability associated with a rapid mushroom growth, the society grew into its present high standing by proceeding slowly and carefully measuring each step. Well aware of the danger associated with a static position, once a definite program was outlined there was no other method of procedure but a forward movement actuated by a cooperative spirit.

In adhering to these fundamentals, supplemented by the self-sacrifice and hard work on the part of many of our members, we have seen ourselves become a very important economic factor in the steel industry. It is this responsibility that we must continue to shoulder. Our organization is recognized as performing a function for the industry that is almost indispensible.

With our mature stature, the outlook for the future must be a long range one. A review of what the "Association" has accomplished seems voluminous. The future is rich in opportunities to serve the industry further with the present critical demands being made for better quality, special requirements for new and unheard of uses and many other problems making up the highly competitive market of today. The ability and cleverness of the engineer in the steel industry is one of most essential factors of the rehabilitation that seems to be at hand.

I come into the presidency of this association upon the heels of a man who understood and deeply felt the responsibility of the society. This was clearly evidenced by the manner in which he conducted our affairs through the critical period following the death of our late and honored managing director, and I take his place with the "Association" further advanced than it was when he assumed his office. We new officers must pledge ourselves to the same goal. The competitive spirit of outdoing our predecessors must always be dominant.

At the present time we are on the threshhold of our 31st. convention and iron and steel exposition. This annual gathering represents the focal point of all our activities. A comprehensive well balanced program for the technical sessions has been arranged. Not only will there be papers and discussions on steel mill operations and developments, but related subjects covering industrial relations and distribution of the products of our industry will serve to interest every executive in the steel industry. Our iron and steel exposition promises to be one of the most interesting in years. The equipment manufacturers reserved their space very early in the year in order to have adequate time in which to prepare educational displays which none of us can afford to miss.

Our path for the coming year is a well defined one. With the aid of the board of directors and the entire membership, we must plan and work diligently to first make this coming meeting the most successful we have ever had and then shape our efforts to coordinate the activities of all of our district sections in order that the year 1935-1936 will be one in which we further the work of the association by utilizing the experiences gained in the past twenty-eight years.

Tentative Program

31st Annual Convention and Iron and Steel Exposition

WILLIAM PENN HOTEL - PITTSBURGH, PA.

SEPTEMBER 24, 25, 26, 1935

TUESDAY, SEPTEMBER 24TH.

9:00 A. M. Registration, Lobby, William Penn Hotel.

Italian Room, Lobby, William Penn Hotel

9:30 A.M.

"Developments in the Iron and Steel Industry 1934-1935" by W. H. Burr, Electrical and Mechanical Superintendent, Lukens Steel Company, Coatesville, Penna.

10:00 A.M.

"A Review of Sheet, Tin and Strip Mills" by Stephen Badlam, Consulting Engineer, Pittsburgh, Penna.

10:45 A.M.

"Run-Out Table Motors and Generators for Hot Strip Mills"

BY

G. A. Caldwell and S. F. Henderson, Westinghouse Elec. & Mfg. Company, East Pittsburgh, Penna.

W. B. Snyder, Industrial Engineering Department, General Electric Company, Schenectady, New York.
L. E. Hildebrand, General Electric Company, Lynn, Mass.

1:15 P.M.

Main Ball Room, 17th Floor, William Penn Hotel

"Industrial Relations" by Arthur H. Young, Vice President, United States Steel Corporation, New York, N. Y.

2:15 P.M.

"Material Handling in the Iron and Steel Industry" by G. N. Harmon, Electrical Superintendent Republic Steel Corporation, Warren District, Warren, Ohio.

3:15 P.M.

"Power Requirements and Other Factors Pertaining to Rolling Hot and Cold Steel" by E. Kieft, Engineer of Tests, Illinois Steel Co., Gary, Ind.

7:30 P.M.

Iron and Steel Exposition Visit by National Officers, National Engineering Committees, Membership and Guests.

10:00 P.M.

Exhibitors Informal Dance, Ball Room, William Penn Hotel, Pittsburgh, Pa.

WEDNESDAY, SEPTEMBER 25TH, 1935.

Italian Room, Lobby, William Penn Hotel

9:15 A.M.

"Processing of Steel in the Finishing Departments" by R. J. Wean, President, Wean Engineering Company, Warren, Ohio.

9:45 A.M.

"The Flat Rolling of Steel" by C. L. McGranahan, Superintendent 76" Hot Strip Mill, Inland Steel Company, Indiana Harbor, Indiana.

10:45 A.M.

"The Manufacture and Use of Iron and Steel Rolls in Carbon and Alloys" by S. H. Griffiths and J. L. Campbell, Ohio Steel Foundry Company, Lima, Ohio.

11:15 A.M.

"Lubricants for Cold Rolling Strip Steel" by Dr. R. W. Moore, Physicist, and E. S. Reynolds, Sales Engineer, Socony Vacuum Oil Company, New York, N. Y.

1:15 P.M. (D.S.T.)

Inspection Trip, Weirton Steel Company, Weirton, W. Va. Special Train which the A. I. & S. E. E. will provide and the guests must use, will leave Try St. Station, Fourth Ave., Pittsburgh, Pa., at 1:15 P.M. (D.S.T.) Price $2.50 per person.

THURSDAY, SEPTEMBER 26TH, 1935.

Combustion Engineering Division
Cardinal Room, 17th Floor, William Penn Hotel

9:30 A.M.

"Insulation of Open Hearth Furnaces" by Gilbert Soler, Manager of Research, Timken Steel and Tube Company, Canton, Ohio.

10:00 A.M.

"The Venturi Port" by George L. Danforth, Jr., President, Open Hearth Combustion Company, Chicago, Ill.

10:30 A.M.

"The Pouring of Molten Steel" by J. P. Walters, Open Hearth Superintendent, and Dr. E. G. Hill, Director of Research, Lukens Steel Company, Coatesville, Penna.

11:15 A.M.

"Roof Temperature Control of Open Hearth Furnaces" by M. J. Bradley, Engineer, Leeds and Northrup Company, Philadelphia, Penna.

Mechanical and Lubrication Engineering Divisions, Blue Room, 17th Floor, William Penn Hotel

9:15 A.M.

"Composition Bearings for Roll Necks and Other Purposes" by H. M. Richardson, Application Engineer Plastics Dept., General Electric Co., Lynn, Mass.

"Progress in the Use of Composition Bearings" by K. T. MacGill, Manager, Glyco-Ryertex Division, Joseph T. Ryerson & Son, Inc., Chicago, Ill.

"Composition Bearings" by H. F. Horn, Engineering Department, Westinghouse Elec. & Mfg. Company, Trafford City, Penna.

10:15 A.M.

"Oil Flooded Bearings for Roll Necks" by J. H. Hitchcock, Engineer, Morgan Construction Company, Worcester, Mass.

10:45 A.M.

"The Development of Specifications for Lubricants" by O. L. Maag, Lubrication Engineer, Timken Steel and Tube Company, Canton, Ohio.

11:30 A.M.

"Cutting Oils" by W. H. Oldacre, Director of Research, D. A. Stuart & Co., Ltd., Chicago, Ill.

Main Ball Room, 17th Floor, William Penn Hotel

1:15 P.M.

"Absorption of Steel in Federal Projects" by Colonel Horatio B. Hackett, Assistant Administrator, Public Works Administration, Department of the Interior, Washington, D. C.

Welding Engineering Division, Main Ball Room, 17th Floor, William Penn Hotel

2:00 P.M.

"Developments in Welding in 1934-35" by Grover A. Hughes, Electrical Engineer, Truscon Steel Company, Youngstown, Ohio.

2:20 P.M.

"Alternating Current Arc Welding" by W. W. Reddie, Industrial Department, Westinghouse Elec. & Mfg. Company, East Pittsburgh, Penna. and E. Steinert, Transformer Engineering Department, Westinghouse Elec. & Mfg. Company, Sharon, Pa.

2:40 P.M.

"Welding in the Steel Industry" by E. W. P. Smith, Consulting Engineer, Lincoln Electric Company, Cleveland, Ohio.

3:00 P.M.

"Welding With the Alternating Current Arc" by H. A. Winne, Industrial Engineering Department General Electric Company, Schenectady, N. Y.

3:20 P.M.

"Developments in the Use of the Oxy-Acetylene Process in the Iron and Steel Industry" by E. J. W. Egger, Resident Engineer, Linde Air Products Company, Pittsburgh, Penna.

Combustion Engineering Division, Cardinal Room, 17th Floor, William Penn Hotel

2:00 P.M.

"Some Applications of Controlled Atmosphere to Heating of Steel" by T. B. Bechtel, Engineer, Electric Furnace Company, Salem, Ohio.

2:30 P.M.

"Recent Developments in Bright Annealing of Sheets and Strip in Electric Furnaces" by A. N. Otis, Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

3:00 P.M.

"Normalizing Furnaces" by W. E. Blythe, District Manager, Driver-Harris Company, Detroit, Mich.

10:00 P.M.

Formal Reception, 17th Floor, Main Ball Room, William Penn Hotel.

IRON AND STEEL EXPOSITION

This coming iron and steel exposition marks the sixteenth under the auspices of the Association of Iron and Steel Electrical Engineers. Starting in St. Louis in 1919 it has grown steadily until today it is recognized as one of the outstanding industrial shows in this country. Held in conjunction with the annual meeting of the society it has proved to be of immense help to the steel mill engineer as well as the manufacturer of steel mill equipment. For the man in the steel plant it has provided an opportunity to view and inspect the latest and most modern designed steel mill equipment. For the steel mill machinery builder it is a natural medium through which he may market his product. Particularly important is this coming iron and steel exposition. Steel Companies are letting huge appropriations for new equipment by which they hope to realize almost the millenium in operating efficiency. The operating officials, in whose hands rests the responsibility of purchasing this new equipment and superintending its successful operation, will journey to the steel show with the express purpose of learning as much as possible about the newly designed equipment which will be on display.

Among the many varied exhibits of the one hundred Companies to be represented in the exposition will be those of manufacturers of mills, bearings, electric motors and control, industrial trucks, couplings, gears, combustion control apparatus, automatic lubricating devices, lubricants, electrical maintenance equipment, safety devices, quite a few of which will be in actual operation thereby giving the exposition the highest possible interest factor.

Exposition Hours

Tuesday 1:30 P.M. to 5:30 P.M. Evening 7:00 P.M. to 10:00 P.M.
Wednesday 10:00 A.M. to 10:00 P.M.
Thursday 10:00 A.M. to 10:00 P.M.

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INDIVIDUAL MOTOR DRIVES

FOR RUN OUT TABLES AND COILERS

By F. E. HARRELL, Asst. Chief Engineer
and C. V. GREGORY, Engineer
RELIANCE ELECTRIC & ENGINEERING CO.

Presented before the A. I. & S. E. E. Thirtieth Convention, Cleveland, Ohio, September 19, 1934

▲IT IS REPORTED that the first installation of individual motors to run-out table rollers was made in the rod mill of the Sharon Steel Hoop Co. about fifteen years ago under the supervision of Mr. Noble Jones. This was later followed by quite a sizeable installation on the Morgan rod mill at the Cambria Plant of the Bethlehem Steel Corporation. One of the first installations of individual drive in the Cleveland district consisted of motors geared through internal gears to rollers for conveying small bars to a preheating furnace where a ninety degree change in direction was accomplished in the length of the table.

With the advent of the continuous mill, the problems of operation and maintenance incident to the means of conveying and disposing of the finished material indicated the desirability of individual motor drive for run-out tables and coilers.

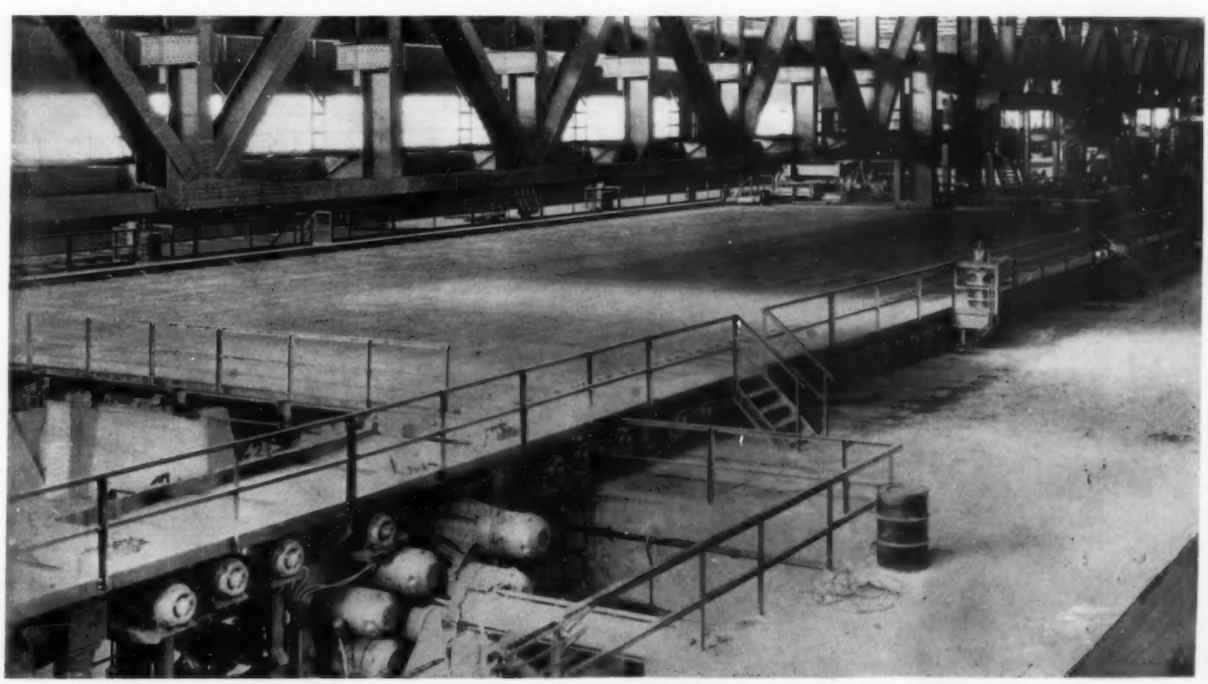
An early sizeable strip mill installation was a run-out table comprising 130 rollers in a single table at what was then the Columbia Steel Company plant at Butler, Pa., where an adjustable-speed direct-current motor was used to drive an alternator for supplying an adjustable frequency to the run-out table motors.

Going back a little over ten years, a Mr. Schulte had introduced an installation at the Duisburg Steel Works in Germany of what is now known as the Schloemann roller. Following an investigation of existing installations in Europe by one of the American electrical manufacturers, an installation of approximately 175 Schloemann rollers was made at a continuous mill in the Chicago district. This installation incidentally marked the first commercial installation of water-cooled motors as such.

One of the largest installations of individual motor drive of run-out tables—over 800 units—is divided between two large tube plants, one in the Pittsburgh district and one in the Cleveland district.

The operation of the earlier continuous mills with individual motor drives on run-out tables, together with the further development in these mills as they have been increased in operating speeds, today dictates the practical necessity of using individual motor drives for

View of Hot Run-out Table and Cooling Bed, Otis Steel Co., 72″ Hot Strip Mill. (Fig. 2.)



continuous mill hot run tables and coilers. It is repeatedly demonstrated that due to some unforseen development in operation or practice, the flexibility provided through such drives is in itself alone sufficient justification for their use.

In passing, it might be in order to repeat some of the principal reasons for the use of individual motor drive, as they have been set forth to you on various occasions before; (1) Simplified table design as absolute continuous alignment between successive rollers is not necessary; (2) Decreased maintenance cost over group drive due to absence of gearing and alignment difficulties; (3) Fewer shutdowns due to ability to cut out single rollers for cause without interrupting mill operations; (4) Increased flexibility of operations with regard to starting, stopping and speed adjustment; (5) Increased ability to accomplish synchronization—by frequency control—of various portions of a table or mill.

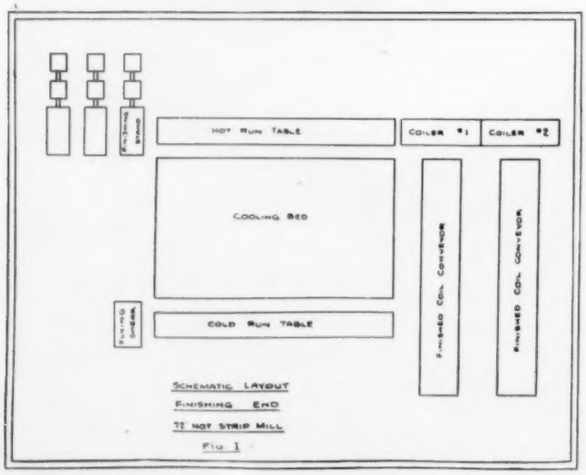
Rather than dealing historically with a complete mill installation, it shall be the intention in this paper to consider the case of the finishing end of a typical 72″ hot strip mill as a type case. The principal considerations entering into the selection of motors and alternator sets for the operation of run-out tables and coilers for such a mill will be set forth for you.

It is desired at this point to give especial acknowledgment for the table and coiler design referred to herein to the United Engineering and Foundry Company and the Otis Steel Company with particular credit for the basic electrical design going to Messrs. R. H. Ellis and J. O'Malia, Electrical Engineers respectively of the aforementioned companies.

It is also desired to give recognition to the Otis Steel Company for the privilege of using illustrations from their 72″ Mill and for the invaluable assistance rendered in the preparation and review of this paper by their Chief Engineer, Mr. C. Clarke Wales.

Figure I shows a schematic physical layout of the mill. You will observe the layout contemplates delivery from the finishing stand to a hot run table 180 feet long from which transfer can be accomplished to a cooling bed on one side for delivery to the cold run table and flying shear, or delivery may be made straight through to either one of two coilers in line with the hot run table. When coiling, delivery is made first to one coiler, then to the second while the first is stopped, unloaded, and again accelerated ready for use.

(Fig. 1)—**Schematic Layout—finishing end—72″ Hot Strip Mill**



The specifications incident to such a mill are—

Number of rollers—	72
Diameter of roller—	10″
Length of roller—	72″
WR^2 of roller—	62.4 lbs. feet squared
Roller spacing—	30″
Maximum loading—	¼″ x 52″ x 150′ strip or 112 lbs. per roller
Mill speed—	600/1200 feet per minute
Roller speed—	230/460 r.p.m.
Rate of operations—	
Hot Bed	2 strips per minute
Coiling	2 strips per minute
Time for acceleration—	
Maximum for table idle	8 seconds
Time of deceleration—	
Maximum from 1200 ft. per minute to be 40 feet of travel or 2 seconds.	

The table must be capable of starting and stopping twice a minute in accordance with the schedule of operations. Provision must be made for starting the entire table as a unit in case of an emergency.

Due to the constructional features of the hot run table, as shown by Figure 2, it may be seen that the side guards and top platform give sufficient protection that an open type motor may safely be used in such an application. Further it was specifically desired in this case to avoid any extra or external means of cooling.

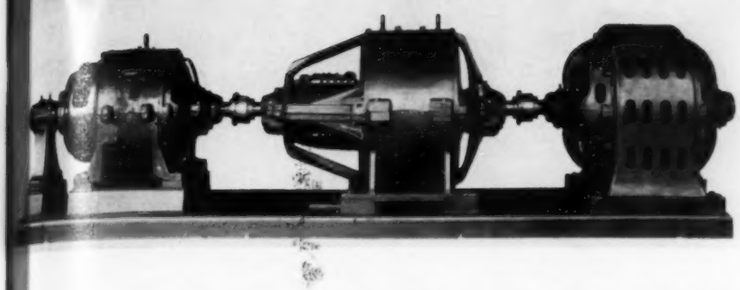
Available power is 230 volts d-c. and 3 phase, 25 cycle, 220 volts a-c.

In order to secure the prescribed range in operating speed, it is necessary to have a supply of adjustable frequency polyphase power over a 2 to 1 speed range. The most acceptable means to this end consists of a direct-current field weakening motor of suitable size, coupled to and mounted on a common base with a polyphase alternator of suitable characteristics for supplying power to the squirrel-cage motors connected to each roller.

Inasmuch as the mill has a 25 cycle supply of polyphase power, it becomes immediately desirable to select a range of frequency which would permit of using the regular mill supply for emergency standby service at a constant speed. Further, recognizing the mill output, it is desirable to have the mill frequency near the middle or upper middle of the full range so that the widest variety of stock might be successfully handled in an emergency from the mill supply.

Since the roller speeds are fixed by mill speeds, the motor speed becomes 230/460 r.p.m. These speeds could be secured from the following combinations of poles and frequency—

2-pole	4/8 cycles
4- "	8/16 "
6- "	6/24 "
8- "	16/32 "
10- "	20/40 "
12- "	24/48 "
14- "	28/56 "
16- "	32/64 "



(Fig. 3)—Three Unit Motor-alternator Set with Breaking Generator in Otis 72″ Strip Mill.

In order to avoid excessive current peaks, since there is to be frequent starting in this case, it is well to avoid the fewer number of poles. At the same time due to the starting requirements, the highest possible torques are desirable, and for this reason too large a number of poles should not be used, since it becomes difficult to secure high starting torque with large numbers of poles and still maintain satisfactory running characteristics. In the light of these considerations and the fact that 25 cycle power is the mill supply, an 8-pole motor with the 16/32 cycle frequency range is selected.

The next item for consideration is torque. Intentionally the mention of horsepower is avoided, since the torques usually required by conditions of acceleration and deceleration are so out of line with reasonable percentages of starting torque to be expected from the horsepowers actually required to power the rollers for running, that it has previously been suggested to your Standards Committee that run-out table motors be rated on a torque basis rather than by horsepower.

From information made available by the mill builders, it is determined that the actual maximum horsepower requirement for running at 1200 feet per minute on such a mill is 0.5.

Acceleration in eight seconds time will permit of group or sequence starting; that is, in order to avoid the excessive current peaks occasioned by unit starting or starting all the motors on the table at one time, it is a proven expedient to divide the table into sections, say three or four, and start the table by these sections successively, bringing in one group after the other so that the current peaks on the system at starting are reduced and a smaller capacity alternator may then be considered.

In this case, since eight seconds for acceleration is permissible, it would appear safe to contemplate a division of the table into three groups of 24 motors each if the motor has a torque and the alternator a capacity to assure acceleration of the idle roller in two seconds. The fact that acceleration to 460 r.p.m. is required in two seconds means that an average starting torque of 50 foot pounds must be provided continuously for two seconds. This figure is obtained from the formula:

$$\text{Torque} = \frac{WR^2 \times \text{R.P.M.}}{308 \times \text{time in seconds}}$$

From the mill data the essential information is available, namely, r.p.m. at top speed is 460, time is two seconds, and WR^2 is 62.4 for roller and an assumed value of say 4 for a motor with .5 for a coupling, or a total WR^2 of 67 pounds feet squared. From this we then get:

$$T = \frac{67 \times 460}{308 \times 2} = 50 \text{ ft. lbs.}$$

Profiting by experience in similar acceleration problems, it is found for a motor having a semi-high torque characteristic, as run-out table motors for the most part should have, that the average torque effective during the starting period is approximately two-thirds of the torque available at the instant of starting. It then becomes obvious that a motor for the present case should have 50 x 3/2 = 75 foot pounds starting torque.

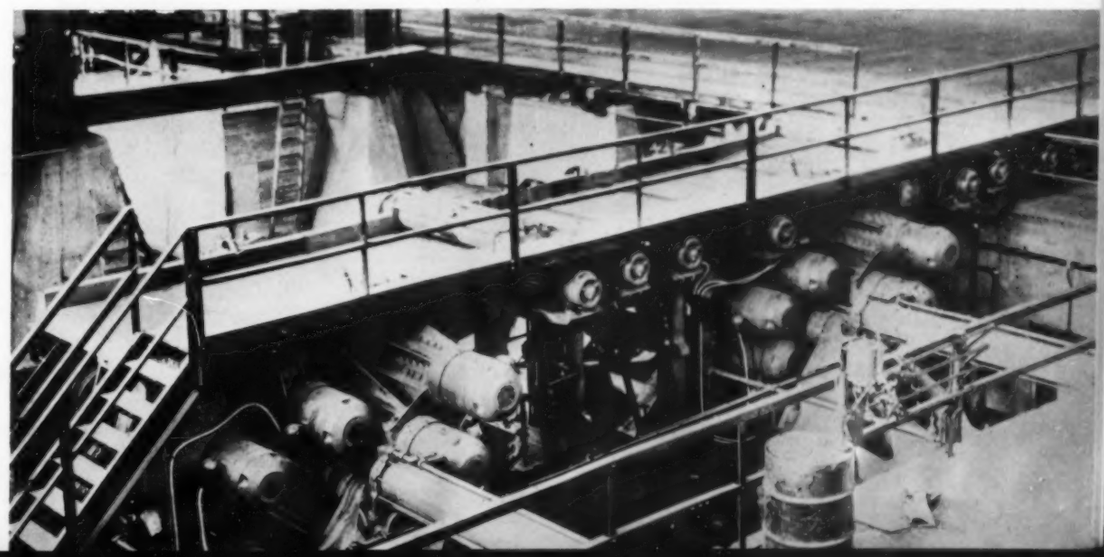
The more difficult problem becomes the one of stopping the loaded table from 1200 feet per minute in 40 feet of travel or two seconds. From the standpoint of motor torque this would necessitate torque as follows:

Roller WR^2	62.4
Load WR^2 112 x $(\frac{5}{12})^2$	19.5
Motor WR^2	4.0
Coupling WR^2	0.5
Total	86.4

$$T = \frac{86.4 \times 460}{308 \times 2} = 64.5 \text{ ft. lbs.}$$

This would mean a motor with approximately 97 foot pounds starting torque and a very large alternator set with sufficient capacity to assure a sustained voltage for producing torque in the motors at stopping. In view of the duty cycle, namely, two strips per minute, the problem of heating is sure to arise due to the high input incident to the high torque if plugged on a-c. Dynamic braking of the hot run table motors through direct-current is therefore considered for the following reasons; (1) Economy in power consumption, (2) reduced frame size of motor, and (3) reduced capacity of alternator set.

A diversion at this time may be justified for a brief consideration of dynamic braking. It is a well-estab-



(Fig. 4)—Two United 72″ Strip-Mill Coilers installed at Otis Steel Co.

lished fact that the application of direct current to the terminals of a polyphase squirrel-cage—or slip-ring—motor will result in a braking effort. This is a perfectly understandable phenomena if you think of your a-c. motor as a motor with fixed poles excited with direct current. The rotor then becomes a short circuited armature rotating in a stationary field, the strength of which can be adjusted by adjustment of the d-c. voltage applied to the motor terminals.

It is a fact then that in this manner braking effort can be secured from squirrel-cage motors at the expense of an input of approximately 50 watts per foot pound of braking effort, whereas by a-c. plugging it is necessary to expend from 100 to 300 watts per foot pound of braking effort, depending on the motor type, poles and frequency. Obviously then d-c. braking involves from one-sixth to one-half of the loss involved by a-c. plugging, and, therefore, means a reduction in heating effect on the individual motor in that proportion.

It is, of course, recognized that the maximum torque available for braking by a-c. plugging is a function of the motor winding and design and not readily adjustable. In the case of d-c. braking it is a proven reality to secure up to 400% of the a-c. starting torque as a braking torque. This is accomplished simply by increasing the current value put through the motor windings in turn determined by the applied d-c. voltage.

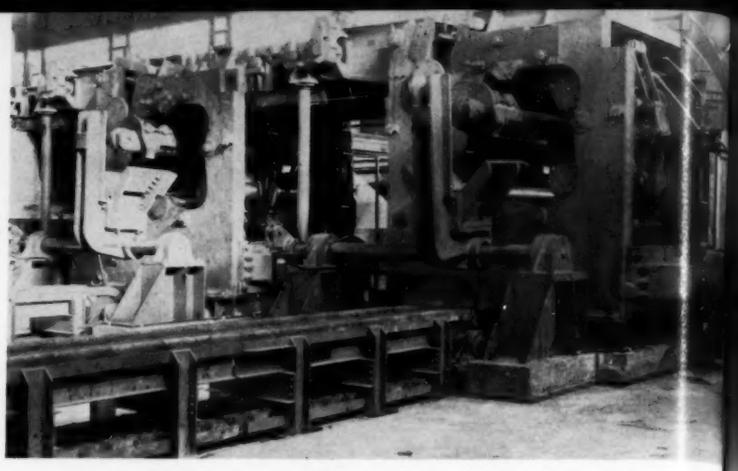
By the same token, then, it is obvious that if a variable voltage is made available for the purpose of d-c. braking a group of motors, then the time of stopping may be readily adjusted over a wide range. In connection with high speed mill operation where slippage of stock on the table is a variable dependent upon a number of factors, the ability to regulate stopping time is a real benefit.

It seems expedient to apply d-c. braking to the hot run table motors both from the standpoint of loss and motor size. The motor torque selected then for satisfactory starting would be adequate for braking, since the limitation would be entirely a matter of the d-c. supply. It is certain that the necessary braking torque of 64.5 foot pounds can be readily secured by d-c. braking from a motor having a value of a-c. starting torque of 75 foot pounds.

It is then determined thus far that the run-out table motor is an 8-pole open motor with semi-high torque characteristics and operating at 16/32 cycles and at a voltage which is proportional to 220 volts at 25 cycles, or 141/282 volts. In addition to meeting these specifications, the motor frame size must be adequate to safely dissipate the total loss incident to the specified duty cycle as follows:

Function	Time	Loss in Watt Seconds
Start	2 seconds	per motor
	8 "	total 6060
Run at 0.5 hp. load	9 "	2930
Stop (D-c. braking)	2 "	8500
Idle	11 "	—
	Total	17490

In a cycle such as the above, it is customary to take the total time, with the exception of the idle time, of which half value is taken, for the purpose of determining the average continuous loss. The time then, for the purpose of determining the average loss, is 24.5 seconds. Dividing the total loss in watt seconds by 24.5, we get the figure of 715 watts as the total average continuous loss.



(Fig. 5)—**Unloading side of Strip Mill Coilers—Otis Steel Company.**

Therefore, the motor must be able to dissipate 715 watts loss continuously, carry .5 hp. load, and develop 75 foot pounds starting torque at 32 cycles. This frame size would be a 324.

This motor must then be designed electrically and is found to have at 32 cycles 282 volts, a locked KW input at full voltage of 11, with a locked KVA input of 14.

The selection of a motor alternator set to power the hot run table may now be made. For the sake of economy the highest speed motor and alternator physically available would be selected. In this case 1200 r.p.m. is recognized as a maximum speed in view of the probable size of the machine. Since a 4-pole alternator would run 960 r.p.m. at top frequency of 32 cycles, 4-pole is selected.

The KVA rating of the alternator should be not less than 75% of the locked KVA total per group of hot run motors. This is an experience factor gleaned from installations of group starting.

Similarly the KVA rating should be not less than 25% of the locked KVA total for all motors on the table, assuming all motors must be started together in an emergency.

To fulfill these conditions the following is obtained:

$$\text{KVA} = .75\ (24 \times 14) = 252$$
$$\text{KVA} = .25\ (72 \times 14) = 252$$

Since these conditions check exactly, an alternator of 250 KVA is selected. The power factor is sure to be low, probably 30% to 70% under different conditions. A 50% power factor machine is usually acceptable. Alternator specifications then are 125/250 KVA, 50% power factor, 4-pole, 3 phase, 16/32 cycles, 141/282 volts, open type.

Experience has similarly shown that for such installations the d-c. driving motor for the alternator set should be not less than 55% of the locked KW total per group of hot run motors. Likewise, the driving motor should be not less than 20% of the locked KW total for all motors on the table.

The motor in this case then becomes—

$$\text{HP} = .55 \left(\frac{24 \times 11}{.746} \right) = 195$$

$$HP = .20\left(\frac{72 \times 11}{.746}\right) = 212$$

Consider that a 200 HP motor should be adequate. Motor specifications then are—200 HP, 230 volt, d-c., open type, shunt wound motor, 480/960 r.p.m.

The braking generator load from the hot run table will be 50 watts per foot pound torque for each of the 64.5 foot pounds required, or 64.5 times 50 equals 3.22 KW per motor. With a terminal resistance between two motor leads given as 2.11 ohms, then it is easy to see since I^2R equals 3220 that I^2 equals $\frac{3220}{2.11}$ or I equals 39 amperes and the terminal volts would have to be 39 times 2.11 equals 82 volts. The braking generator must then have a capacity of not less than 75% of the peak KW required, or for this case—

$$KW = .75\ (72 \times 3.22) = 174$$

Use a 200 KW generator with 100 volt potential for top table speed.

Such a braking generator may be driven either by a separate motor—synchronous or squirrel-cage—or by the d-c. driving motor for the table alternator. If the braking generator is used for table motor only, then it is clear that the loads appear alternately on alternator and braking generator, so that it may safely be added to the d-c. driving motor load. It is recognized that with the speed variation of the driving motor, the terminal voltage of the braking generator will vary directly. Adjustment of the generator field is necessary for different conditions of operation anyhow, and this means is proven entirely practical.

Figure 3 illustrates such a 3-unit set consisting of a 1300 ampere braking generator on the left, 200 HP adjustable-speed direct-current driving motor in the center with a 250 KVA alternator on the right.

Coming now to the coilers it should be clearly understood that the reference herein is specifically to the outside expanding reel similar to those as built and installed on most modern strip mill installations by the United Engineering & Foundry Company and the Mesta Machine Company.

Operation of such a reel may be more readily understood from a study of Figure 4, this being a 72″ United Engineering & Foundry Company reel. Strip is received on the coiler-approach table from the hot run table. The operator at the pulpit will select the coiler to be fed by treadle operation of a pneumatic cylinder opening the feed gate of the appropriate reel.

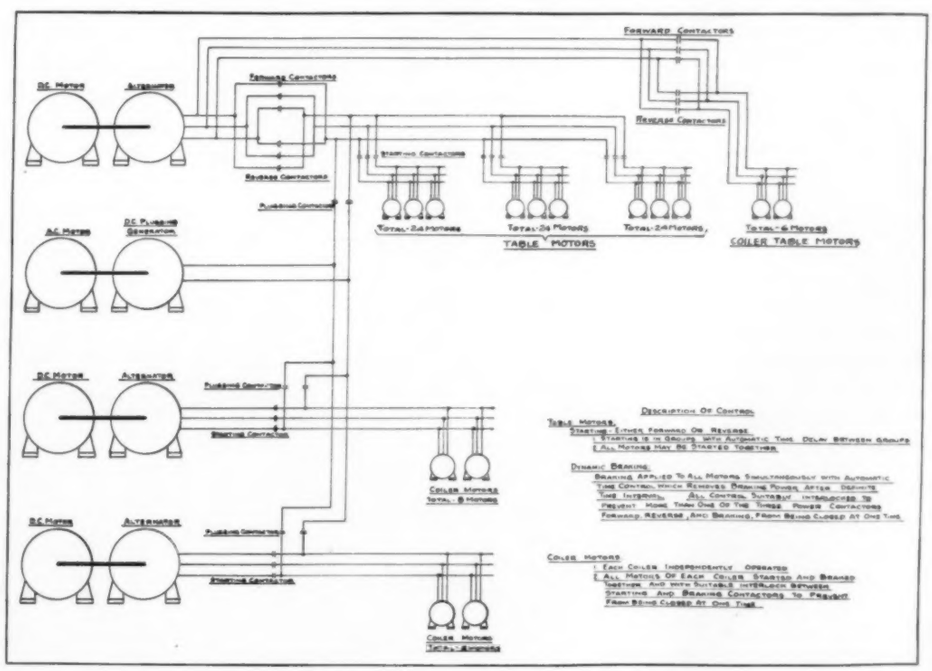
The reel is comprised of six main rolls and two guide rolls each driven by a direct-connected fan-cooled motor. The guide rolls are capable of adjustment to permit of their operation as pinch rolls when and if desired. The four lower main rolls are supported on pivoted arms, the outer ends of which are interconnected by links to accomplish uniform movement in expanding the reel.

The strip on passing through the charged rolls on the coiler-approach table starts the operation of the low-speed d-c. cam motor. The cam motor drives through a reduction unit to a cam which in turn actuates a valve for pneumatically controlling the rate of opening or expanding the reel.

On completion of reeling a coil, the coiler is stopped by d-c. braking in view of the great inertia existing in the heavy bundle rotating at such high speed. The bundle is then ejected by the long air-operated ram onto a chain-type conveyor system.

On completion of the coil ejection, a second high-speed d-c. cam motor quickly returns the cam and rolls to the loading or starting position, the overtravel to the low-speed cam motor being permitted through a free-wheeling mechanism.

Figure 5 shows the unloading side of such a reel.



(Fig. 6)—Schematic Layout—Control for Hot Run-out Table and Coilers.

Specifications pertaining to motors for such a reel might be—

Number of rolls	—8
Diameter of roll	—14″
Length of roll	—72″
WR^2 of roll	—192 lbs. feet squared
Maximum loading	—3500 lb. bundle
Coiler speed	—500/1500 ft. per min.
Roll speed	—137/411 r.p.m.
Rate of operation	—One strip per minute per coiler
Time of acceleration	—Idle—up to 12 seconds
	—Loaded—must be capable of starting in emergency
Time of deceleration	—Loaded—3½ seconds from 1500 ft. per min.
Minimum running torque per roll	—105 ft. lbs.

Motors must be low slip in order to avoid as far as possible speed variations between rolls due to variation in loading. Motors must have high maximum torque to avoid stalling under extreme or emergency conditions and high starting torque for the same reason.

Due to mechanical clearances incident to the design of such a reel, there is apt to be a limitation to permissible diameters for motors for the coiler roll. Due to the normal conditions existing around the coiler, the motors must be watertight. Since it is quite impossible to anticipate straight fully-enclosed motors from the standpoint of heating, it is necessary to use either fan-cooled, pipe-ventilated or water-cooled motors for this application.

With motor speeds fixed at 137/411 r.p.m. and allowing some slip, possible combinations to secure say 150/450 r.p.m. would be—

2-pole	2½/ 7½	cycles
4- "	5 /15	"
6- "	7½/22½	"
8- "	10 /30	"
10- "	12½/37½	"
12- "	15 /45	"
14- "	17½/52½	"
16- "	20 /60	"

Mechanical clearances having fixed the maximum diameter of the motor and with the further requirement of 105 foot pounds running torque, we are immediately shut out of the use of anything over 10-poles because of space limitations.

For such a purpose it is undesirable to include a range of frequency below 10 cycles on account of operating characteristics. The winding is, therefore, automatically limited to 8 or 10-poles, since with the use of an 8-pole winding, the frequency range becomes such that it presents a possible combination for operation at 25 cycles constant frequency with the hot run table, this winding is selected.

For starting torque at the emergency condition, in view of alternator regulation, it is expedient to provide a torque of sufficient value to produce acceleration in a theoretical time of four seconds, recognizing the fact that due to the normal voltage regulation under this overload on the alternator, the actual time of acceleration will be more like 10 to 15 seconds.

This torque would then be calculated as follows—

Load WR^2	160
Roller WR^2	192
Motor WR^2 (Assumed)	12
Total	364

$$T = \frac{364 \times 411}{308 \times 4} = 121 \text{ ft. lbs.}$$

This would mean a motor starting torque of 1.5 times 121 equals 182 ft. lbs.

The motor then becomes a motor having 105 foot pounds running torque wound for 3 phase, 8 poles, operating at 10 to 30 cycles, 150 to 450 r.p.m. synchronous speed, 88/264 volts, and with 182 foot pounds starting torque. The fan-cooled enclosure is selected and becomes the frame 405.

To check the heating of this motor it is necessary to establish the d-c. braking cycle.

To stop in 3½ seconds by d-c. braking, the torque is calculated as—

$$T = \frac{364 \times 411}{308 \times 3.5} = 139 \text{ ft. lbs.}$$

At 50 watts per foot pound torque, this indicates an input of 50 times 139 equals 6.95 KW per motor. With terminal resistance of 1.2 ohms, then I^2R equals 6950, $I^2 = \frac{6950}{1.2} = 5800$. $I = 76.2$ amperes. Voltage necessary equals 76.2 times 1.2 equals 91.5 volts. Total braking capacity—

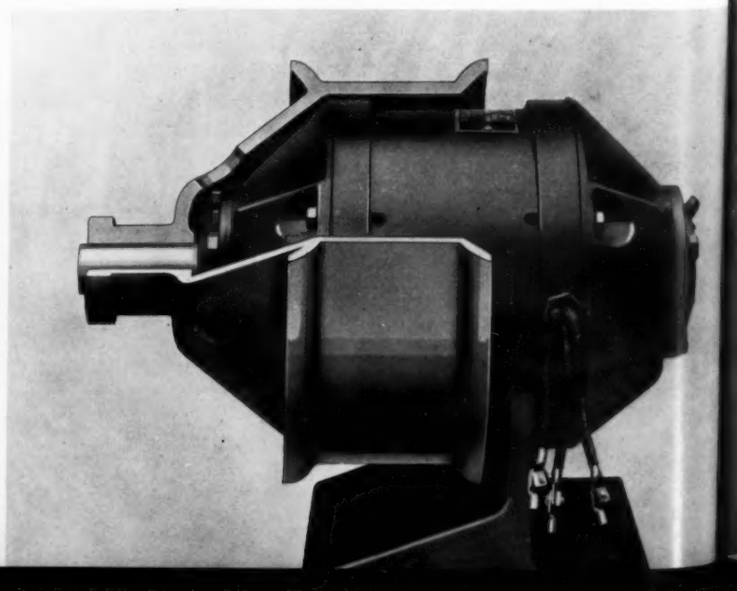
$$KW = .75\ (8 \times 6.95) = 41.7$$

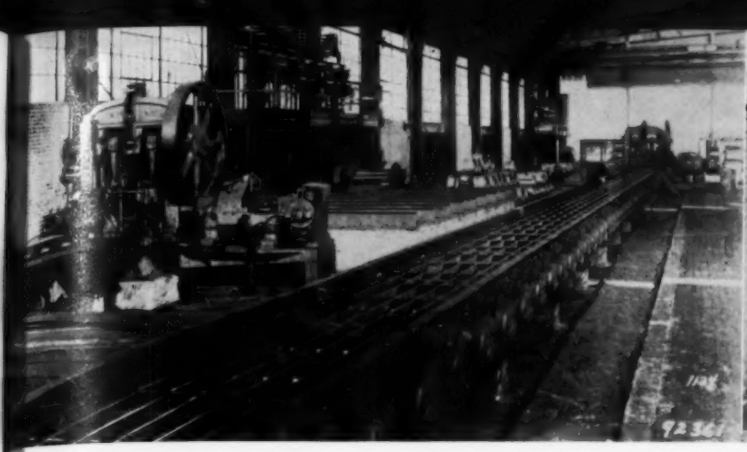
Since the voltage is sufficiently close to that required for braking the hot run table, and since the hot run table in regular operation is not braked with the coilers, then the same braking generator may be used in this particular case for both the hot run table and the coilers.

Checking the heating now for the whole cycle, it is found to be—

Operation	Time	Loss in Watt Seconds
Starting	10 seconds	14,700
Run at 3½ HP load	10 "	6,100
Stop	3½ "	15,500
Idle	6½ "	—
Total		36,300

(Fig. 7)—Pulley Type Roller and Web-foot Motor for handling "Cotton-tie".





(Fig. 8)—Built-in Motors of a type used on an early strip mill installation.

(Fig. 9)—Internal Ring-gear type of Individual Motor-drive.

*The effective time for this duty cycle is computed as 27 seconds, taking half of the idle time, consequently the average continuous loss is 36,300 divided by 27 or 1,340 watts.

Since the 405 frame is capable of dissipating over 1400 watts continuous loss, this frame is acceptable.

From the electrical design of this motor, it has been found to have a locked KW input at full voltage of 20 and a locked KVA input of 33.5.

For the greatest flexibility it is desirable to have separate motor-alternator sets for each coiler. For the selected frequency range then it seems desirable to use a 4-pole alternator running 300/900 r.p.m.

By experience it is found desirable to have an alternator for this purpose of not less than 50% of the locked KVA of all motors thrown on it.

This means—

$$KVA = .50\ (8 \times 33.5) = 139$$

By experience it is found desirable to have a driving motor of not less than 33% of the locked KW of all motors powered through it.

This means—

$$HP = .33 \left(\frac{8 \times 20}{.746}\right) = 71$$

The motor alternator set then will be—

Motor—75 hp., 230 volts, d-c., shunt wound, 300/900 r.p.m.

Alternator—50/150 kva., 50% power factor, 3 phase, 10/30 cycle, 4-pole, 88/264 volts.

Now that the motors and motor-alternator sets are selected, it might be in order to observe the scheme of their control. Figure 6 shows a schematic layout of a possible control of the hot run table and coiler.

Starting and stopping of the motor-alternator sets is possible only from the control room—not at the operator's pulpit. The operator's pulpit contains a reversing drum master switch for the hot run table for starting the 72 motors in three groups of 24 motors each. The first group contactor closes with the main contactor, while the two successive group contactors close in succession at a time determined by a timing relay attached to each. By this master switch the table is started by groups in either the forward or reverse direction.

For emergency operation there is an additional drum master at the pulpit for starting the hot run table as a unit either forward or reverse. Stopping of this table under any condition is by d-c. braking, the d-c. braking contactors being opened by a timing relay a predetermined number of seconds after closing.

A full field relay is provided so that whenever the table is started in any manner, full field is placed on the alternator for a predetermined time which is sufficient to permit all three contactors to go in on sequence starting—this to assist in maintaining better voltage regulation at starting.

Adjustment of the speed of the table is secured by remote control from the pulpit through a motor-operated rheostat.

For each coiler a drum master is provided for starting in the forward direction only, and stopping by d-c. braking. Starting is always accomplished with full field on the alternator. Adjustment of coiler speed is by remote control from the pulpit as with the table motors.

Inasmuch as the entire attention thus far has been of such a highly technical nature, it is in order to introduce at this time a review of the economics of individual drive, together with a consideration of the various types of enclosure and mountings including gear motors.

It is the intention in this part of the paper on the subject of "Individual Motor Drives for Run-out Tables and Coilers" to consider the various types or forms of motors used, or available for use, on such applications and to point out briefly the commercial angle involved as it affects the initial cost, the simplicity of construction and operation, with its attendant problem of complete maintenance.

To go back a few years to the advent of the continuous mill, the motor manufacturer was called upon to design a motor satisfactory for the conditions involved and yet in the majority of cases adapt this required power unit to the mill table design and construction. This usually resulted in an entirely special squirrel-cage motor of an off-standard type of mounting.

The flexibility of the squirrel-cage induction motor with its simplicity of design and construction contributing, the electric motor manufacturers found themselves supplying squirrel-cage induction motors of every type and description to meet the various problems presented by roller drives on steel mills for all classes of material.

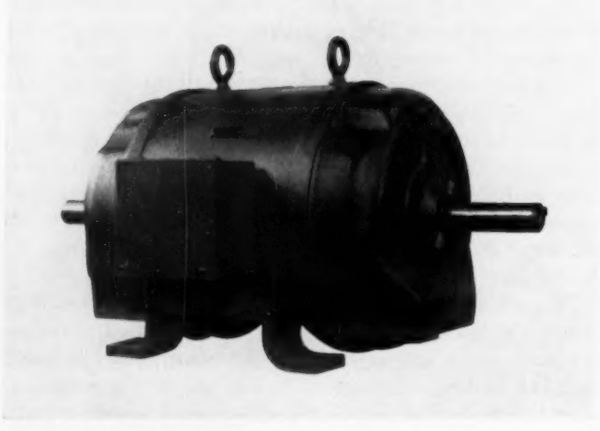
A typical unit indicative of this trend is shown in Figure 7. This construction combined a motor and roller designed for use on a short narrow width mill for conveying "cotton tie", small rounds and bars. The motor had a frame with a web foot mounted slightly off the center line toward the pinion end of the motor. A pulley or roller designed and built with close clearance around the motor frame was then keyed to the

motor shaft. These motors were necessarily special and were wound with class B insulation on account of the high ambient temperatures under which they were required to operate.

A familiar construction used on hot run table rollers in connection with continuous strip mills made use of an "overhung motor". Figure 8 shows an installation of some 130 motors on such a table. The motor rotor is mounted on an extension of the roller shaft and the stator is mounted on or bolted to the mill table frame work. One bearing bracket and both bearings were eliminated in this construction.

Various other forms or adaptations of the squirrel cage induction motor were designed and built for these applications, but in practically every case some mechanical limitations or objections to these drives developed. They were particularly out-moded in light of the improvements and developments in design together with the additional knowledge of table roller drives and mill operating requirements gained through these initial installations. Specially designed built-in motors still have their place on certain applications, but in the final analysis special apparatus of any kind carries a certain tariff that adds to the original investment involved.

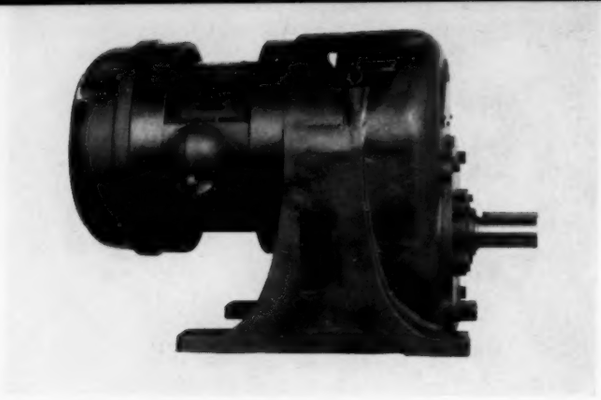
On some early applications, standard motors were also used, particularly where the mill operation required a geared drive. These usually were of two forms—the separate reduction unit and the internal ring gear drive.



(Fig. 10)—Splash-proof Motor.

The separate reduction unit consisted of a suitable conventional reducer coupled to a motor of proper characteristics for the drive involved. Such construction was used where a large ratio of reduction was dictated by a slow mill speed of heavy duty torque requirements. One such installation of some 800 units consisted of a motor, reducer, and roller, all coupled and mounted on one common bed plate forming a self-contained roller unit.

The internal ring gear drive made use of an internal ring gear in the end of the roller and engaged with a pinion on the motor shaft. Figure 9 shows such an



(Fig. 11)—Single-stage Gearmotor.

installation that was used for conveying billets from a furnace around a corner table to the mill. These drives are limited, however, to those requiring a low ratio of speed reduction.

The modern continuous strip mill with its hot run table and coilers presents a separate problem, however, from the standpoint of individual motor drives for the table rollers. High speed operation with its corresponding severe duty cycles of rapid acceleration and deceleration have resulted in the use of a direct connected motor in the majority of cases. This is particularly so on the new modern mills where rollers of from 9″ to 16″ diameter are being used to handle steel at delivery speeds ranging from 600 to 1600 f.p.m. and with coilers operating at speeds of 800 to 2000 f.p.m. Several contemplated drives are anticipating delivery speeds of the finishing end running as high as 2000 f.p.m. This trend toward higher operating speeds with its resulting problems of acceleration and deceleration necessitate an increased use of direct connected motors with dynamic braking on these individual rollers on hot run tables.

Primarily, of course, a direct connected drive resolves itself into the use of a conventional motor having standard NEMA mounting dimensions and electrically designed for the duty cycle involved. The construction is rugged and simple resulting in a saving in first cost as well as in cost of maintenance. From a design standpoint, particularly on duty cycles involving rapid acceleration and deceleration, the direct connected drive has decided advantages. From the mill builders point of view simplicity of motor drives means simplicity of mill table construction—and simplicity in any form means decreased installation, operating and maintenance expense within the plant.

On two recent continuous strip mill installations, the mill builder provided on the hot run table a motor mounting so protected from falling scale, dirt and water, that open motors are being safely used.

Adaptations of the 40° C. rated open motor can, of course, be obtained for these applications. The fully-enclosed, fully-enclosed fan-cooled, pipe or force ventilated, splash proof and water cooled construction are all available where the conditions require some sort of protection to the motor windings. All are standard adaptations of squirrel cage motors with means inherently or to be provided externally for keeping the temperature rise within certain definite limits as specified by NEMA for such construction.

In passing, it might be well to point out the protection offered a squirrel cage motor having splash proof

construction. This unit is sufficiently new to the steel industry, particularly on such applications as table roller drives, to bear further consideration. The design consists primarily of an open motor with bearing brackets provided with an opening placed close to the floor line. Figure 10 shows such a construction. The openings serve as air intakes which with the aid of the rotor fans causes circulation over the heads of the coils and stator core. The air leaves the motor through openings at the bottom and sides of the motor frame. Long air passages and low velocity of this air reduce the possibility of moisture or dirt being carried into the motor. This construction is not intended for locations where the air is constantly dust laden or where best engineering judgment dictates the use of a fully-enclosed motor. It does, however, provide the kind of protection where the motor might be subjected to occasional showers of dirt. This design incidentally is essentially self-cleaning, any dirt dropping out through the middle openings. Open motor ratings are obtainable in this construction with mounting dimensions and weights essentially the same as those of the corresponding open type motor except that the temperature rise is 50° C.

You are all well acquainted with these other various forms of enclosure and the advantages gained through using a construction which provides protection to the windings, air gap and bearings. Only a mention need be made that for a small addition and in no case more than 25% to 30% addition to the open motor cost is required on the initial investment to provide some degree of protection to lessen future maintenance.

Where the motors operate in a relatively high ambient temperature class B insulation of the stator windings is another desirable feature that can be obtained at a reasonable additional cost.

Direct connected drives are of course preferred as long as the conditions involved can be met satisfactorily. However, the occasion arises where geared drives are required to meet certain conditions common to a particular installation such as space limitations or necessary clearances common on double cooling bed or transfer table installations. On such drives, the modern gearmotor presents advantages over and above other means of similar transmission of power as to bear further consideration on applications of this sort.

The most popular types of gearmotors today for use on table rollers consist of a simple gear train made up of helical or herringbone gears with suitable ratio of reduction to meet the operating speed of the mill. Anti-friction bearings throughout the gearmotor coupled with this type of gear construction tend toward smooth operation with relatively high efficiency.

Figure 11 shows a single stage gearmotor typical of a type for consideration on table roller drives. Full support close to the point of maximum torque application is made possible through a construction having the feet of the unit an integral part of the gear housing.

Figure 12 shows a splash proof multi-stage gearmotor.

In some cases, therefore, where table structure or space limitations do not permit the use of a direct connected motor and a geared drive becomes necessary, gearmotors with their lower first cost and improved performance due to their higher motor speeds, are usually worthy of further consideration. It must be recognized however, that a gearmotor while eliminating the line shaft common to group drive still has introduced gearing between motor and roller.

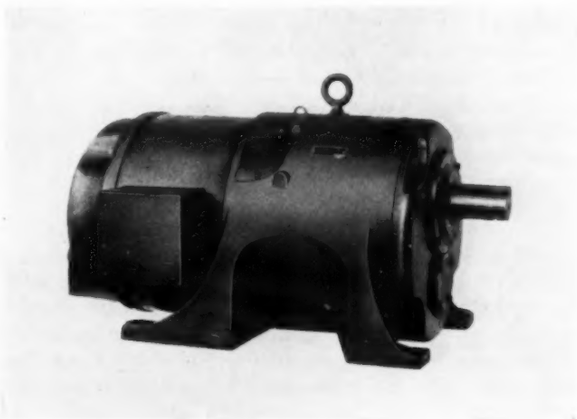
Considerable might be said on this question of group drive versus individual motor drive. The merits of the latter are particularly apparent when applied to the modern high speed mill with its necessary flexibility of operation and control.

From the standpoint of initial cost of a complete hot run table installation, there is apt to be little difference in the overall cost of group drive including gearing, motors and control as compared with the cost of the individual motor drive including couplings, motors, control and motor alternator set. The principal exceptions are apt to be short tables of limited capacities where group drive might be appreciably less expensive. As a matter of comparison, it has been estimated by a prominent mill builder that for a 200 ft. hot run table the probable total cost of equipment covered above for group drive would be approximately $23,000.00 as against $17,000.00 for corresponding individual motor drives.

The fact remains that the modern mill, particularly the finishing end, is being powered with individual motor drive. The contributing reasons are largely incident to the simplicity of construction resulting in economical installation costs, reduced maintenance costs and increased overall efficiency permitting outputs from a modern 72″ mill of as high as 100 tons per hour.

This complete paper has necessarily been somewhat technical and abstract, but it will have served its purpose if it has pictured for you the modern continuous strip mill with its hot run table operating at delivery speeds as high as 1400 f.p.m. and coiling at speeds as high as 1600 f.p.m. and yet so closely controlled as to enable stopping this end of the mill from these speeds in two seconds; you will have in brief the contribution to modern mill practice of individual motor drive and dynamic braking through direct current on these motor drives.

(Fig. 12)—Splash-proof Multi-stage Gearmotor.



IMPORTANCE OF REPLACEMENT

OF OBSOLETE EQUIPMENT IN STEEL MILLS

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Presented before the American Iron and Steel Institute at New York, May 23, 1935

▲IT IS NATURAL that a subject which emphasizes the importance of economics in relation to replacements and obsolescence should be of interest to American Iron and Steel Institute, because no other industry has torn itself down and rebuilt itself to a greater extent than the steel industry. This is apparent when we think of the present size of iron and steel producing units and how they have grown through successive generations, from blast furnaces of 5 and 25 tons capacity to modern blast furnaces of 1,000 to 1,500 tons; from open-hearth furnaces with 10 tons capacity in 1886 to modern open-hearths with 150 tons capacity or more. Each time there was a substantial increase in capacity of these furnaces, it meant, in general, a complete replacement of the unit. Many men working in our steel plants today have seen the complete rebuilding of their department as often as three times in 30 to 40 years of service.

Economics is defined as the science which investigates the conditions affecting the production, distribution and consumption of wealth. In this discussion it may be defined as a study of the conditions which affect the probable profit which may accrue from certain expenditures intended to improve the earning capacity of a steel mill. Such studies will usually take the form—"Shall the replacement be made?"—"Shall it be done now?"—"Shall it be done this way?"

Obsolescence may be defined as the loss in service value due to diminished earning capacity caused by advancement in the art or changes in market conditions which demand a quality of product beyond the ability of the unit, or demand a quantity greater than can be produced, or less than is economical. This process may be a gradual one, the unit becoming less valuable by a small amount each year, or it may become obsolete over night.

It should be noted that as soon as one venturesome soul makes a radical change in the size, or otherwise improves a producing unit and successfully puts it into operation, all other such units which are not as efficient as the new one must be considered obsolete.

A casual survey of our subject will reveal that it is utterly impossible to cover, in the short space of time available, all of its phases as related to the steel industry. Therefore we will start our discussion at the point where the raw materials arrive and stop where the finished or semi-finished product leaves the steel plant.

In thinking of replacements, a logical discussion can be laid out on the basis of what causes a replacement to be made. These causes can be grouped into four general divisions.

First: *A unit may be replaced because it is worn out.* This classification covers all types of furnaces, machinery, buildings and even foundations, because by their use their component parts become worn and they are affected by atmospheric conditions, which cause deterioration—rapid or slow, but always in some form. Repairs, of course, tend to retard this gradual wearing out, which is quite frequently called depreciation. The accounting profession has set up elaborate systems for accumulating reserves to cover depreciation so that when the unit is finally retired from service its value may be removed from the books without loss. Units which depreciate rather rapidly and which are replaced several times in one year, or even once in two or three years, are frequently covered by what is known as a rebuilding fund rather than a depreciation reserve. In these cases it often occurs that at the end of ten years, the unit, having been rebuilt many times, has been improved here and there, and so far as results are concerned may be a somewhat better unit than when it was originally built. In spite of this, however, there has been a certain depreciation of other parts which are not so easily improved without replacing the entire unit.

We have other units which, while not badly worn, except for some one or two parts, are finally renewed because of the failure of one of these parts, making it necessary to renew not only the part which caused the failure, but also many other parts. The repairs to such a unit are usually made in such a manner that the defects in materials or design are corrected and that a failure of the same kind is not to be expected in the future.

Replacements under this classification may be considered as being caused by depreciation rather than by obsolescence, but when the time comes when repairs are needed to so many parts that a replacement should be made, all the information which has been gathered in the operation and maintenance of the unit should be utilized so that the replacing unit is better than its predecessor.

D. M. PETTY

Second: *A unit may be replaced because it is not producing a satisfactory product from a consumer point of view.* This classification may be sub-divided into two parts:

(a) Where the unit does not produce as satisfactory a product as it did when originally installed. It may sometimes occur that the unit may be diverted to other lines of work and yield several additional years of service. Nevertheless, if the market is to be supplied with the product of such a unit, a new unit must be installed.

(b) Where the unit still produces as good a product as when originally installed, but where demands of the market have materially increased since the original installation, and the unit is not able to meet the increased requirements, it then becomes a matter of deciding whether the new unit shall be installed to meet the current market requirements or whether considerably greater refinements shall be included in order to satisfy not only the immediate demands, but also to anticipate possible additional requirements. That action may have the effect of attracting additional customers for this particular unit, thereby increasing its saleable output. That very condition may make it apparent that a unit of greater capacity is desirable. A careful survey must be made in order to determine the probable future market for these products so as to avoid the possibility of installing a unit and finding, shortly, that the market for its products has disappeared.

When a new unit is installed which is capable of producing a somewhat better product than is currently on the market and which the users of such product can and will absorb to their advantage, the obsolescence of all the other units producing the same product whether they are in that plant or competing plants is immediately advanced.

Accelerating obsolescence in all other units may or may not be good economics, depending upon such factors as increasing the number of potential customers by virtue of a better product and by entering into an entirely new field hitherto not invaded by this particular product.

Third: *A unit may be replaced because the cost of production on this unit is high, and therefore the profits, by virtue of its operation, too low.* This may be caused by many factors which a new unit might correct, such as excessive cost of repairs because the unit is too light for its work, or where its parts are worn to a point where the replacement might properly be put in the first classification. The labor costs for operating the unit may be excessively high, which may be caused by an attempt to get out greater production than that for which the unit was designed, thereby necessitating additional men in greater proportion than the increased production. The man-hours remaining stationary, the increased cost may be due to a general increase in the rates paid to the operators. The man-hours may be materially increased to improve the quality of the product and to make it meet the demands of the trade. The economy of the unit, as related to its fuel, power or raw material consumption may be low. This low efficiency may be due to an inherently poor original design or to the gradual wear and tear of all or certain parts of the equipment. The high cost of production may be caused by material increase in the cost of raw materials used. This increase, in turn, may be caused by an exhaustion of the local supply, thereby necessitating bringing materials from more distant points; or it may be caused by an increase in freight rates, even to the point where the raw material originally used is dropped and something substituted in its place, such as oil for coal, electricity for gas, etc. A change in the social laws may require extra men or unusually high expenditures for supplementary equipment. Necessary safeguards against accidents may become such an item of expense as to make replacement necessary.

When making a replacement, due to the high cost of production on the existing unit, there is always a tendency to install a unit of greater capacity because, generally speaking, a greater output means lower unit cost.

Fourth: *A unit may be replaced because more capacity is desired.* The first consideration in this case is, shall additional units be added to the equipment already in service, or, shall some of the existing units be removed and larger ones installed in their places? Where quality is not adversely affected by an increase in the size of the unit, or where seasonal fluctuations in demand are not excessive, the larger unit almost universally will be more efficient and show lower operating costs per unit of production. Where the total number of units is limited, substituting one large unit for a number of small units might leave the department inflexible as to tonnage during dull periods, especially if several grades of a product are required to meet market conditions.

In reaching a conclusion on this point the reduction in operating and maintenance costs of the larger unit must not be overlooked. In the past the trend of the steel industry has definitely been toward larger units.

Whether this trend will carry on to still larger units remains to be seen, but the lessons of the past few years will enable managers and engineers more accurately to arrive at the correct solution of this question for their particular plant.

It is evident that there is a very close relationship between depreciation and obsolescence and that either one must include the other. That is, if a high depreciation rate is set, a replacing fund may be set up before the unit has become obsolete, which is another way of saying that the unit will wear out before it becomes obsolete. There has been much discussion as to how the remaining part of the original cost shall be disposed of when a unit is to be replaced because it has become obsolete. One school of thought would add this undepreciated remainder to the cost of the new unit. Another school insists that this undepreciated remainder is a loss and must be so considered and charged off at once; that it is unsound economics to charge against the new unit anything which pertains to the old. This latter policy would appear to be more sound than the former, because it prevents building up a capital structure not supported by real values in plant and equipment.

It would appear that it is rather improbable that the correct depreciation rate can be set at the start of operations of each unit, even in a small plant. Therefore some average figure should be set up for the entire plant to provide a depreciation reserve so that some units will be depreciated before they actually go out of service, while others will be taken out of service before they are depreciated to their scrap value, the remainder being charged to this reserve at once.

The economics of replacing obsolete equipment, i.e., equipment which fails to measure up to the present day standards of efficiency, is more a matter of management than of accounting, and it may prove to be better business to scrap an entire plant and replace it with a modern one, if improvements in the art have been so rapid that the decreased manufacturing cost in the new unit will earn greater profits than the old plant even with its considerably less capital charge. Capital charges in this case include interest, taxes, depreciation and/or obsolescence.

From a management point of view, it may be utterly impossible to keep an obsolete plant in operation. This may be caused by such factors as: First: decreased selling prices, caused by competition, which may be lower than the manufacturing costs in an obsolete plant. Here it is obvious that no profit can be earned. Second: The quality of the product offered by competitors with modern plants may make it impossible to sell the product of an obsolete plant, which certainly means that no profit can be earned on the old plant. Third: The difference in manufacturing costs between the modern plant and the obsolete plant may be such as to make the new investment even better than the original investment, the selling price having remained the same. This theory may be reduced to a general mathematical formula.

Cn equals Unit cost of production for the new unit.
Co " Unit cost of production for the old unit.
Pn " Annual production capacity of new unit.
Po equals Annual production capacity of old unit.
K " % of time new unit will average in operation over its life.
D " % of depreciation for new unit.
O " % of obsolescence for new unit.
Z " Total profit per unit of production on new unit.
A " Total cost of new unit.
M " Cost of money in annual percentage.

$$[(Co-Cn)\,Po + (Pn-Po)\,Z]\,K - [(\text{The greater of } AD \text{ or } AO) + AM] \div A \times 100 = \%\ \text{profit.}$$

It should be noted that in applying this general theory or formula to a steel plant, there is one factor which must never be overlooked: it is entirely futile to enlarge any one unit to such an extent that it is entirely out of step in producing capacity or in speed of production to those units which are just ahead of it and supply its incoming material, or in comparison with the succeeding departments which take its output. The continuous flow of steel through the plant must not be interrupted. Of course this does not mean that improvements in a unit which affect costs and quality only cannot be made without a corresponding change in the preceding and succeeding units, because it is logical to improve the weakest link in the chain of production rather than rebuild the entire chain, so long as the capacity of the unit is sufficient to supply the market.

An inspection of this formula will reveal one obvious fact: the first part of the equation, that is, the savings per unit multiplied by the annual capacity of the old unit plus the increased annual capacity of the new unit multiplied by total profit per unit and all by the load factor, must be greater than the other factors which are to be subtracted, otherwise there can be no profit.

$$[(Co - Cn)\,Po + (Pn - Po)\,Z]$$

The two factors, old unit cost and new unit cost, are usually rather easy to determine and the difference between these two unit costs will be fairly constant. An increase in the cost of raw materials will affect both factors alike except that, generally speaking, a new unit usually has a better practice percentage than the older unit, which will tend to increase the difference in cost with a rise in raw material cost. In the matter of labor, as a general proposition, new processes or new machinery involve less labor per unit of production; therefore as the cost of labor in general increases, the difference in unit cost will be greater and in favor of the new unit.

The producing capacity of the new unit is a matter of design and must be determined in advance by a very careful study of the market trend. Ordinarily, unless the market trend is upward and a greater volume of business is expected, a new unit should not be considered, and certainly will not be considered if the market trend is downward.

THE FACTOR "K"

The most uncertain quantity in the formula is the load factor "K". This represents the average percentage of time the new unit will operate at full load each year during its life. Management must examine the market trend to determine both what the past exper-

ience has been, and something about the future, not only with reference to the present outlets but also as to the possible additional outlets for the product, such as how much wider will be the distribution of the particular product if its selling price can be reduced or its quality improved. A condition which may materially affect this factor is change in buying habits of the public or a change in the style of the product. If the product is a staple commodity, such as pig iron, the probability of any great change in the demands of the buying public is considerably less than if the product is one which is subject to frequent style changes. In some cases, the product in question may be only an adjunct to the principal commodity, so far as the ultimate sale is concerned. For instance, the steel rim for mounting solid rubber tires for trucks has reached a rather stable condition so far as its particular design is concerned, but the market for solid rubber tires is rapidly disappearing, owing to the fact that highway commissions have virtually ruled a solid tire truck from the highways, and the demand for greater speed from trucks has made the solid rubber tire impractical. Therefore, it would be poor economics to make an investment in equipment for manufacturing rims for solid tires.

Seasonal demands can sometimes be met by operating the manufacturing processes at a more or less continuous rate throughout the year and storing the surplus production during the slack sales months in order to meet the rush demand at the other seasons of the year. Whether it is better policy to operate at a steady annual rate and store against the rush season or to install equipment sufficient to meet the rush season demands and shut down this particular unit during the dull season, is one which can be answered only after a detailed study of the product in question. A factor which must not be overlooked, however, is that labor should be given as regular employment as possible.

The general trend of the consumption of iron and steel products has been upward for many years. The consumption of a particular steel product will always show a very rapid rise shortly after the time of its introduction, followed by a period of leveling off and occasionally followed by a period of declining consumption. This is shown in the production of steel rails which reached its peak in 1906 and has been falling off ever since. On the other hand, the production of sheets and strips is increasing. This illustrates the point that the long term load factor "K" of a finishing unit will always be lower than that of the primary departments such as the blast furnace and open-hearth or than the service departments which include transportation, electric power, steam and water departments. As the demand for one finished product decreases another may increase to such an extent that the demand on the open-hearth for steel ingots may be the same, and the demand on the service departments even greater because of the more highly finished nature of the product.

For instance, the energy required for rolling and finishing one ton of a light product like thin sheets is much more than that required for such products as heavy structural shapes, plates, or rails.

THE FACTORS "AD" AND "AO"

The second and third, or subtractive parts of the equation, also must be very carefully studied. The item "A", which not only enters into the subtractive portion but is also the divisor when determining the percentage of annual profit, varies from time to time. During a period of high construction costs, certain improvements will not be profitable, but with a material decrease in the cost of the various items which enter into a construction program, the same improvement might become profitable.

The item "AD", which is depreciation, may be calculated from the probable life of the machine or equipment in question, and, in general, the depreciation factor should be sufficient to set up a depreciation allowance equal to the cost of the unit less its scrap value at the time it becomes so worn that it is no longer efficient. This is a proper charge to include in operating cost, because it is merely a process of transferring a portion of the original cost of the equipment into its product which is sold. A careful engineering survey of the unit will ordinarily reveal a figure which will be proper to cover this wearing out process. If conditions change, it may be necessary to either increase or decrease this figure so as to provide the proper depreciation reserve. Sufficient funds will then have been provided to prevent a loss when the unit has been worn out and must be retired.

The factor "AO" is not subject to the same mathematical calculations as "AD" because obsolescence is not a matter of wearing out, but rather a matter of earning capacity. This may be affected by the demand for the product of a unit decreasing because its cost is so great it cannot be sold or because the public no longer desires such a product, or for many other reasons, none of which, however, may be connected with the wearing out of the unit. Generally speaking, in the earliest stages of development of any new process, the obsolescence on equipment will be high because the operator of the equipment will invent improvements which will tend to lower the cost or improve the quality of the product to such an extent that the original equipment is no longer commercially useable. Therefore, in general, changes in equipment, where the processes are relatively new, should be delayed as long as possible in order to take advantage of the latest improvements, of course, never delaying such a change to the point where the losses are too great or where lack of quality in the product might result in loss of its market. Generally speaking, it is also true that during the early stages of development of a process the market demands are growing so that additional equipment of more modern design can frequently be added without scrapping the original equipment which can then be held for peak business operation only.

It should be noted that these two factors "AD" and "AO" are not to be added, but set up independent of each other; i.e., depreciation should be set to provide against wear and tear only and obsolescence should be set to provide against loss of service value. The latter is a matter of judgment and if it is the larger, the former does not count since the unit will be replaced before it wears out, assuming that the judgment of the management was correct in setting the obsolescence rate.

THE FACTOR "AM"

The remaining subtractive item in the equation "AM", the cost of capital with which to make improvements, is one which must be carefully surveyed and it may frequently happen that an improvement cannot be justified at one time due to the high cost of money and may be entirely feasible at some later time when the cost of money has decreased.

If there is a large cash surplus on hand, on which a very small return can be earned in the money markets, certain improvements may be made with much more certainty than if funds are scarce and must be borrowed. In general, there are few avenues of investment for surplus funds better than in needed improvements that stand the test of "Shall it be done?" "Shall it be done this way?" and "Should it be done now?"

In surveying this general problem, there are several rather obvious conclusions:

First: Improvements in service departments can be made on a lower net return than in manufacturing departments, because in general their load factor is higher and their obsolescence factor lower.

Second: Since the primary departments, i.e., blast furnace, open-hearth, bessemer and electric furnace have a higher load factor than the finishing departments, improvements here can be made with better assurance that they will be used than is the case with the finishing departments.

Third: It becomes necessary to make improvements in certain finishing departments when they cannot meet competition of other producers or when they cannot meet the demands for quality from customers, whether the return on the investment is all that is desired or not. For this reason investments in finishing departments will always be a greater risk than in the primary and service departments.

Obsolescence to some extent can be postponed by improving component parts of equipment. For instance, the cylinders and pistons may be replaced with new ones of improved designs or the valve gear may be changed on existing gas or steam engines, materially improving their operation.

Supplementary roll stands may be added to existing mills or a steam engine may be replaced by electric motors as the main drive, control apparatus can frequently be applied to existing electric motors so as to improve their performance or increase the speed of the mill in order to increase production or improve quality by reducing the temperature drop between entering and finishing passes.

Equipment for controlling the rate of cooling of the finished product may be added to existing hot-beds in order to improve the quality of the finished product.

The art of welding has made possible changes to, as well as facilitating maintenance of, equipment which were formerly virtually impossible.

PATENTS

In the above discussion, processes and equipment have been considered without any regard to patents, but in many cases the patent situation cannot be ignored. For instance, the selling price of a product covered by a patent may be maintained at a relatively high figure. At the expiration of the patent, the selling price may possibly be materially reduced, and this reduction may expand the market to such an extent as to make this an even more attractive field. On the other hand, it may take away business from a competing product to such an extent that its production is no longer profitable and the equipment for its production obsolete.

It is also true that if a process or a piece of equipment is covered by a fundamental patent, obsolescence can be held within certain limits during the life of the patent and additional protection against obsolescence can frequently be obtained by application of improvement patents. However, it is dangerous economics to depend entirely upon patent protection for holding a market for any given commodity because the greater the potential profit in such a product, the greater will be the effort put forth by potential competitors to devise ways and means of avoiding the patents which cover it, and, the greater the competition will be at the expiration of the patents.

In considering the subject of this discussion more concretely it might be well to replace some of the words in the title so that it reads: "The Profitable Application of New Ideas to the Steel Industry."

This application in some cases may involve a complete replacement of certain equipment or process, in others only a modification. The only purpose of this part of the discussion will be to suggest possibilities, rather than try to prove the case for any particular idea; such a proof would have to be predicated on many local factors such as the cost of coal delivered to the plant, what part of that cost was transportation, labor, losses, etc. This would set the value of a B.t.u. The market for by-products would also have to be known. The available labor would have to be studied: can it be trained to handle complex operations efficiently, or must such things be avoided?

SERVICE DEPARTMENTS

In the transportation division a new tool is rapidly proving itself, the oil engine as applied to a locomotive. Such a locomotive has many advantages over the present-day steam locomotive for yard shifting as evidenced by the large number that were put into service last year as compared to the steam locomotive.

The use of roller bearings is rapidly proving its case against the conventional bearings, especially for cars which must carry heavy loads and where the breakaway friction is an important item, or in places where heat thins out the grease or oil in the conventional bearing, or where excessive dirt necessitates frequent renewals of brasses. This is a typical case of where the improvement can be added to existing units.

In the steam department the modern steam generator is finding favor, not only because it is a very efficient unit, but also because it adapts itself very nicely to the job of burning the last remainder of by-product gas, supplemented automatically by powdered coal or oil.

The waste heat boiler as applied to gas engines, both for electric power generation and for blowing blast furnaces, has long been in use abroad and now has proven

its case in this country, improving the thermal efficiency of the gas engine 30% and being practically automatic in its operation. Except where the value of fuel is very low and where the load factor is less than 50%, the return on the investment in these units will vary from 50% to more than 100% per year.

Closely allied to the steam department is power generation, not only because of the use of steam turbines, but also because the waste heat boiler referred to above makes it possible to generate power on gas engines somewhat cheaper than ever before, not forgetting that the design of gas engines has been materially improved by better ignition, more scientific lubrication, use of special valve rigging to insure the exhaustion of all the burned gases from the cylinders and supplying a full charge of fresh air to furnish the necessary oxygen for complete combustion.

It would now appear that an ideal electric generating station for a steel plant is a battery of gas engines of either 4,000 or 8,000 kw. capacity each, depending on the aggregate size of the station, equipped with waste heat boilers supplemented by some steam turbine capacity, to use the steam not only from the engine boilers, but also from the boiler plant which uses the last remainder of by-product gas.

The electrical department is finding it advantageous to replace many old and high cost motors with motors of more modern design equipped with anti-friction bearings, their windings enclosed in a dust-tight cover, but sometimes ventilated by means of a fan. Also modern automatic control for motors can give the producing operators what they need in the way of speed to reduce cost.

PRIMARY DEPARTMENTS

One of the principal improvements to the coke plants of the future will be simplification of design to reduce first cost. This new design will also include much better heat insulation and generally improved refractories.

Dry quenching of coke has very definite possibilities where the value of a B.t.u. is great or water is at a great premium.

The meeting place of the coke and ore is the blast furnace. Here the trend is to ever larger units.

The most attractive field for improvement of existing blast furnaces lies in the production and use of the gas. This may be accomplished by better stoves, the improvement taking the form of higher blast temperatures and lower fuel ratio, or a reduction in the gas burned in the stoves with a greater amount left for other purposes. The more efficient stoves require good gas cleaning and the modern electrical precipitation gas cleaners offer a saving in cost over the present-day mechanical cleaners sufficient to yield a net return on the investment in the order of 30% to 50% and even up to 100% where the cost of power and water is very high.

The modern gas-engine-driven blowing engine, delivering blast at 18 lbs. pressure, requires only 13.47 B.t.u. per cu. ft. of free air in the form of blast furnace gas and will also yield 0.003 lbs. of steam from its accompanying waste heat boiler. With the value of gas at 13c per million B.t.u., the net blowing cost of such a unit will be in the order of 25 to 30c per gross ton of pig iron in a 600 ton furnace, and less in a larger furnace.

OPEN-HEARTHS

Recent improvements in open-hearth furnace design have been largely for the purpose of reducing the fuel required per ton of steel manufactured. Processes in the open-hearth furnace, of course, have been materially improved also, but these processes, generally speaking, can be applied to an old furnace almost as well as to a new one, provided the old furnace is capable of producing temperatures in the bath sufficient to cause the desired reactions. Improvements in the thermal design of the furnace, therefore, may be used either for the purpose of reducing the B.t.u.'s required per ton of steel, or to increase temperature in the bath in order to improve the quality of the steel manufactured.

Many of these improvements, in general, can be and have been applied to furnaces at the time of their normal rebuilding, except where space limitations do not permit sufficiently large regenerative chambers to be constructed. Under these conditions, and especially when new furnaces are being designed, it would appear that a portion of the regenerative chambers built entirely separate from the furnaces, as in the case of a blast furnace stove, might offer many advantages. The smaller furnaces in large open-hearth departments have become obsolete because the larger furnaces, in the order of 150 tons capacity, have shown considerably better operating costs.

Automatic control of the fuel applied to the furnace, by pyrometers suitably located in the roof, have permitted the roof to be insulated with a material increase in roof life over what was normal in the past, as well as a reduction of both fuel consumption and time required for making a heat. Improvements may be applied to a limited number of furnaces which can be operated at a high load factor, so that a greater yield on the improvement cost can be realized than if all were improved.

The present-day processes of making steel are rather contradictory inasmuch as the metal is refined in the open-hearth, or even the electric furnace, until it is in as nearly a perfect condition as possible. It is then tapped into a ladle and teemed into ingot molds where it is allowed to cool to solidification. In this process whatever impurities remain in the steel, together with certain alloys that have been purposely added, separate from the steel and concentrate in the center and near the top of the ingot, making it necessary to discard quite a percentage of the entire ingot to eliminate this undesirable part. It is a problem worthy of our best minds to devise a process whereby this segregation will not take place and we can take the ingot, or whatever its new name might be, and finish it complete for shipment to the customer.

ROLLING MILLS

The roughing or blooming mills usually supply blooms or bars of some form to a number of finishing mills and consequently work at a better load factor. Since there is usually a limited number in any plant, they must be reliable units, as the entire output of the open-hearth department must flow through these first mills. Improvements have largely been along the line of making

these units more reliable or increasing their capacity. Application of the electric motor has improved the control that the operator has over the mill, making it possible to roll slow or fast. Also, where desired, automatic screw-down control can be arranged so that the draft per pass can be limited and a definite number of passes set up so as to insure each ingot being rolled similarly.

The general trend of the demands of the consumers of steel is for products that are more and more highly finished. Structural steel seems to be drifting toward sections of lighter weight but greater strength, and the finishing tolerances are becoming more and more restricted. This means closer rolling tolerances, and improvements in mills and mill operations must have this in view. Accurate temperature control will be necessary not only in the heating furnaces but also as the piece moves through the mill. The speed of the mills must be constant, so that each piece will finish in about the same time from the furnace.

Steel must be rolled to very accurate sizes, which requires finishing stands of great rigidity and finishing temperatures accurately controlled.

The heat treatment of steels to meet the requirements of the trade is calling for better furnaces and much more accurate control of temperature than ever before, as well as control of furnace atmosphere.

The steel industry takes its raw materials from the earth at the places where nature left them, assembles them at the mill, and, after several major metallurgical and mechanical operations, ships a rather highly finished product to its customers. These operations require a tremendous investment in mines, land, buildings and equipment at a rate of about $65.00 per ton of ingot producing capacity.

With 90% activity it requires well over two years for the sales value of its products to equal its invested capital. This means that in times of maximum volume of business, a 10% profit included in the sales value represents a return of somewhat less than 5% on the investment. No profit can be made at a low volume of business without a substantial increase in selling prices or a great reduction in operating costs.

This is a very different picture from that presented by industries which purchase their raw materials in a semi-finished state and convert them quickly into finished form for sale, and where a turnover of the capital investment can be made in one year, or from certain merchandising chain stores where the capital invested is turned over five or more times per year.

Money paid to workers in the steel industry represents 41% of the sales value of its products.

Only 75% of the ingot tonnage manufactured is shipped to the customer.

The cost of repairs and maintenance is about $8.00 per ton of product shipped or $224,000,000 per year as an average over the past ten years.

These figures offer a vivid explanation of why obsolescence is of such vital importance to the steel industry, and why each piece of equipment which proposes to reduce the man-hours per ton, increase the ratio of ingots poured to product shipped, or reduce the cost of maintenance, must be carefully as well as eagerly surveyed to determine its true economic value.

Working Model of HOT STRIP MILL to be Displayed at Iron and Steel Exposition

AMONG the many interesting features of our coming iron and steel exposition will be a complete working model of the Youngstown Sheet & Tube Co.'s new hot strip continuous mill. The model literally reduces tiny slabs to sheets.

Starting from two "furnaces" that faithfully depict appearance of the big gas fired chambers where slabs are heated to proper temperature to meet exact metallurgical specifications, the toy slabs move through a scale breaker on to the 23-foot stretch of rolling mill equipment that terminates in a pair of "flying shears" which cut the strip into desired lengths. In this area the four "roughing" mills and six "finishing" mills which extend over a distance of about 500 feet in the plant proper, are reproduced with functioning rollers whose weight and timing are exactly to scale.

The series of four four-high "roughing stands", each representing two rollers of 100,000 pounds and two of 22,000 pounds in horizontal arrangement, are first in line. They are followed by automatic sizing and cleaning devices in replica. Then the elongated toy slab moves out over an open area to the six finishing stands which function exactly as the series in the mill weighing five million pounds.

The finishing stands are perfectly synchronized, so that in the miniature mill as in the original a single strip of metal may actually be going through the rollers of all six stands at the same time. Each successive stand operates faster than the one previous, and must function just enough faster to receive the strip as it passes from the preceding stand at increased speed and reduced thickness.

Working model of the Youngstown Sheet & Tube's Hot Strip Mill.

SELECTION OF EQUIPMENT

FOR DC POWER IN ROLLING MILLS

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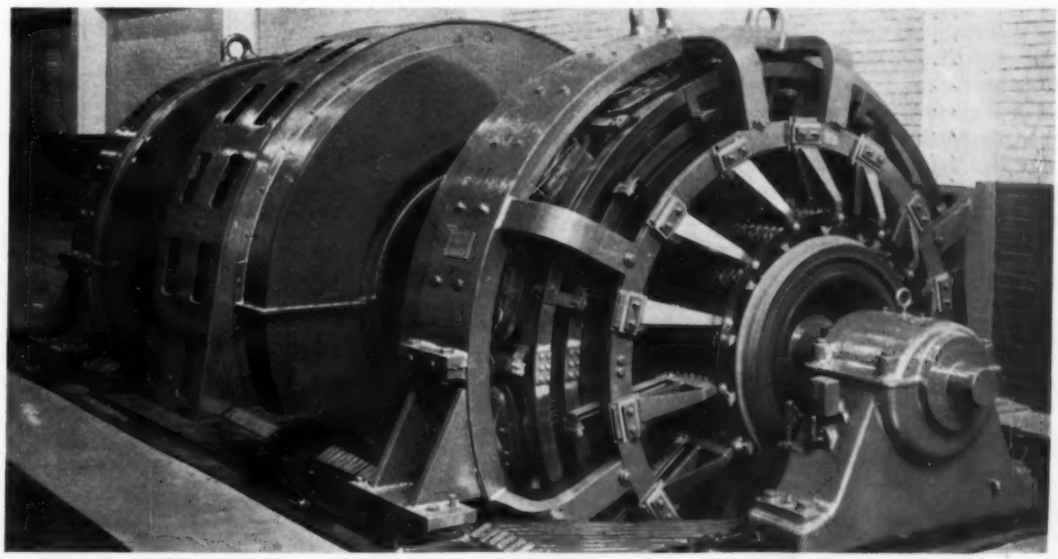
Presented before the A. I. & S. E. E. Spring Engineering Conference, Youngstown, Ohio, April 24 and 25, 1935

▲THE SELECTION of the power supply chosen for driving the motors of a continuous rolling mill is influenced by two major factors, the capacity required and the operating performance desired. These two factors are of necessity inter-related.

Practically all power supplies consist of motor generator sets, the A.C. motors being of the synchronous type. Synchronous motors are preferred as they are cheaper, more efficient, and provide power factor control. Induction motors, larger than 1200 H.P., are generally built of the wound rotor type instead of the squirrel cage type, in order to secure a lower inrush of current during starting. The control for these motors is more costly and complicated than that for the same size synchronous motor. From the performance standpoint, the synchronous motor, operating at constant speed, does not influence the D.C. generator voltage as does the induction motor, whose speed varies slightly with load.

The use of conversion equipment instead of prime mover driven D.C. generators is obvious, particularly since it permits the power supply being located in the motor room of the mill. In order to secure lower costs, higher efficiencies and minimum space requirements, relatively high speed motor generator sets are used, namely, 1000 k.w. at 750 r.p.m., 1500 k.w. at 500 r.p.m., 2000 k.w. at 500 r.p.m., and 3000 or 3500 k.w. at 375 r.p.m. To gain still further economies, the larger sets are usually of the 3-unit type, two duplicate generators being driven by one large A.C. motor. Modern large capacity mills, using 12,000 to 16,000 k.w. generator capacity, require the stable operation of these generators in parallel.

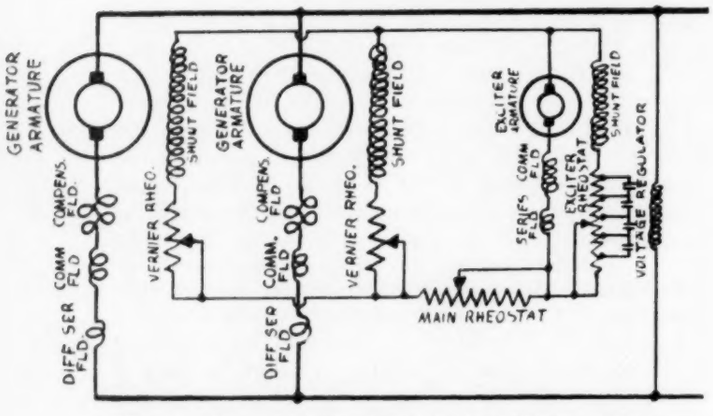
Experience over a considerable period of time indicates that the best overall operation results when the voltage of the generators is controlled by a voltage regulator, rather than attempting to secure the desired voltage regulation inherently in the generators themselves. Generators for use with voltage regulators may be either of the straight shunt wound or of the slight differentially compound wound type, separately excited in either case. The use of a slight differential series field results in better inherent division of load between the several generators in parallel, with no question as to the requirement of an equalizer. It also eliminates the detrimental effect of heavy circulating currents at minimum or residual voltage. Thus, it is not necessary to open the line breakers when the gen-



Continous steel mill motor generator set.

erator voltage is reduced to residual and the motors are at a standstill; neither are "suicide" nor bucking shunt field connections necessary to eliminate detrimental circulating currents and creeping of the motors. Such generators can, therefore, be operated in parallel without equalizers from residual to rated voltage when starting up the mill, eliminating the necessity of starting the mill with some of the generators only and then paralleling the remaining at normal voltage before starting the rolling operations.

Voltage regulation of any D.C. machine is influenced by the constancy of the supply frequency, the temperature changes of the generator, the permanency of the manufacturer's original test floor adjustments, and the fluctuations of the excitation supply voltage. The voltage regulator corrects the voltage regulation for



(Fig. 1)—Diagrammatic sketch of two differentially compound wound d. c. generators.

variations in any of these factors and holds the voltage essentially constant even with load changes, irrespective of the inherent voltage regulation of the generators themselves.

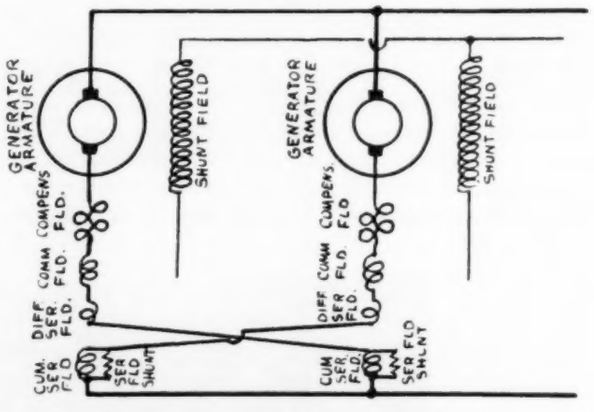
It would be possible to use a voltage regulator on each generator, but by using one common separate exciter for supplying the excitation of all generators in parallel and applying a voltage regulator to the field of this exciter, the size of the voltage regulator is reduced, with accompanying reduction in attention and maintenance. With the regulator working on the field of the exciter, a theoretical delay in exciter voltage response results. However, by employing a "high speed of response" type of exciter, this time delay is practically eliminated, producing a highly satisfactory operating system.

In order to provide a means of securing equal division of load between the generators in parallel, especially when first starting up the mill, a Vernier or small range rheostat is connected in the field circuit of each generator. Figure 1 shows schematically the diagram connections for two 3-unit motor generator sets, such as are described above, operating in parallel under voltage regulator control.

The accepted method of starting and bringing up to speed simultaneously all the D.C. motors driving a continuous mill, is by means of variable voltage from the power supply generators.

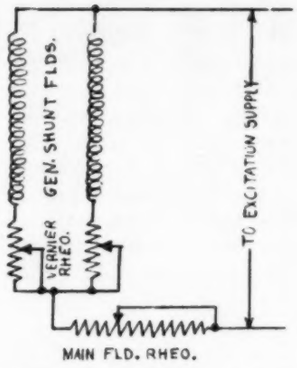
In the first applications of continuous mill generators, straight flat compound wound generators having a single cumulative series field were supplied. These generators gave fairly satisfactory inherent voltage regulation but they would not share the load particularly well when operated in parallel, especially when operating at reduced voltages. It was thus necessary to use one generator only for starting the mill motors. When the motors were up to speed and the generator voltage again at its normal value, the remaining generators were paralleled, providing full power supply for the system.

An improvement was secured in providing the generators with differential series fields as well as cumulative series fields. If these fields were of equal strength, shunting the differential series field would give a predominance to the cumulative series field and approximately flat voltage regulation could be secured. The same results could, of course, be secured by having more actual turns on the cumulative series field. In order to secure the maximum degree of load division, the series fields of two duplicate generators operating in parallel were crossed, as shown in Figure 2. No equalizer is necessary in this scheme of connection. In operation, if generator A for any reason started to take more than its share of load, the extra current in its own differential series field would lower its voltage, thus shifting some of the excess load to generator B, and at the same time the extra current of generator A flowing in the series field of generator B would raise its voltage, making it take an increase of load, thus further reducing the excess load on generator A. The

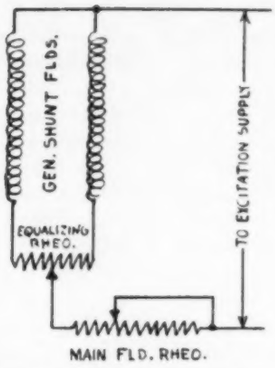


(Fig. 2)—Diagrammatic sketch of two flat compound wound d. c. generators.

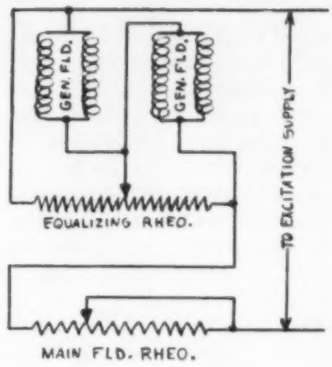
shunt fields of generators A and B can either be connected in parallel or in series and operated as a unit. If connected in parallel, a Vernier or small range rheostat must be connected in series with each field to permit adjustment for initial equal load division. This can be accomplished either as shown in Figures 3(a) or 3(b). The connection shown in Figure 3(b) is preferable as a slight reduction of the field strength of one generator is simultaneously accompanied by an increase of the other. If the fields of each generator are connected for half voltage excitation and the fields of the two generators connected in series, a shunting rheostat



(Fig. 3a)—Shunt fields of two generators connected in parallel, each with its own Vernier or equalizing rheostat.



(Fig. 3b)—Shunt fields of two generators connected in parallel, with a common Vernier or equalizing rheostat.



(Fig. 3c)—Shunt fields of two generators each connected in two parallel circuits.

generally of the form shown in Figure 3(c) is employed.

When two or more such 3-unit sets are operated in parallel, each set is connected as shown in Figure 2 and two equalizers are generally used as indicated in Figure 4. Another method of operating three or more of these duplicate generators in parallel is indicated in Figure 5, where the cumulative series fields are staggered progressively. No equalizer connections are used in this case.

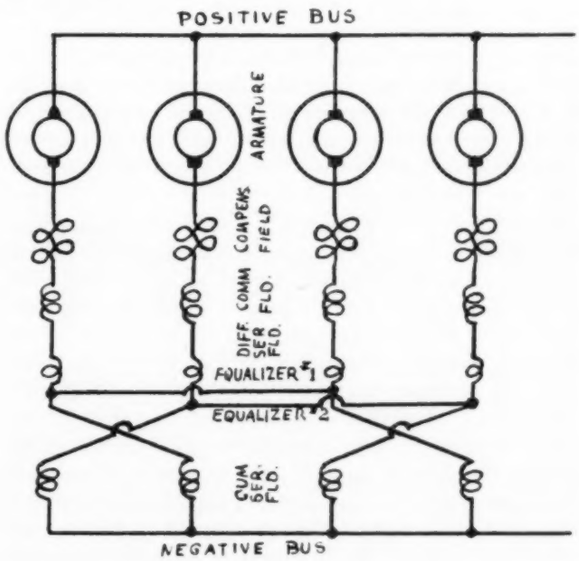
Since it was difficult to obtain inherently in the D.C. generator power supply itself a sufficiently constant voltage under all conditions of operation, and at the same time secure satisfactory load division without undue complications, the flat compound wound generator has been superseded in modern steel mill installations by the voltage regulator controlled generator.

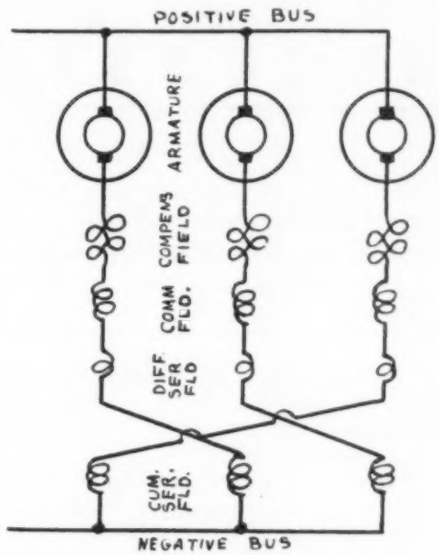
Even with a practically constant generator voltage supply, it should be noted that speed control of the various motors in a continuous mill depends not only upon the constancy of supply voltage, but involves the motor characteristics themselves, as well as the control equipment.

Another source of D.C. supply is the synchronous converter. This type of conversion apparatus does not meet the requirements of continuous steel mill operation in that it is essentially a fixed voltage machine. It would be difficult and complicated to provide a control scheme that would maintain constant voltage over the wide range of loads and varying operating conditions encountered. Neither could it furnish a variable voltage from residual to normal nor supply a reversed voltage for backing up the rolls, when this is occasionally required. Starting the mill would thus have to be accomplished by the armature resistance method. On account of these limitations, synchronous converters are not used for a power supply for continuous mills.

Modern motor generator sets used for power supply are made of fabricated steel construction. They may be of the open, self ventilated type, although most are

(Fig. 4)—Diagrammatic sketch of four compound wound generators.





(Fig. 5)—Diagrammatic sketch of three duplicate flat compound wound generators.

supplied with rear end bells for forced ventilation.

The use of rolled steel for the frame provides not only a better mechanical structure, but also better magnetic material. The brush rigging of welded steel, so constructed that no welds carry current, results in a strong and substantial structure. Bronze die cast brush holders with the brush boxes accurately machined to size prevent chatter and vibration of the brushes. Double brush holders provide additional advantages in permitting more intimate contact between the brushes and commutator surface. The divided brush offers more resistance to circulating currents of commutation as a further improvement in commutation. Compensating or pole face windings are used as they impose less duty on the voltage regulator and give superior commutation at high overload swings. These features, together with the developments made in commutator construction in the past few years, provide a D.C. power supply for continuous mills that gives satisfactory and uninterrupted service under the loads and overloads encountered in modern high speed continuous mills.

▲

DISCUSSION

PRESENTED BY

H. A. WINNE, Industrial Engineering Dept., General Electric Co., Schenectady, N. Y.

G. E. STOLTZ, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

H. A. Winne: I think Mr. Lynn has given us a very interesting and instructive paper, it is especially timely, as it seems as though every steel plant which doesn't have a continuous strip mill either is putting one in or wishes it could. What we are going to do with all of them after we get them remains to be seen.

Mr. Lynn mentioned the desirability of synchronous motors on motor-generator sets supplying power for continuous mills. I agree with him heartily, but would like to say a word of caution in connection with the power factor for which the motors are designed.

Today a great many mills have so much synchronous apparatus on their power systems that they are beginning to be worried by too much power factor correction rather than by poor power factor, and it is particularly important that mills which are in that shape should study rather carefully this question of rated power factor of additional synchronous apparatus. It is not enough simply to say "Let's buy an 80% power factor set and we can use it at any power factor we want to." This may lead to difficulty for if you have a synchronous motor designed for normal operation at 80% leading power factor, and you reduce its field excitation so as to raise the power factor to 90% or 100%, the available maximum torque of that motor is very considerably decreased because of the reduction in excitation, and you may find your motor pulling out of step when you least wish it to. For this reason in some of the more recent mills the synchronous machines have been built for normal power factor of 90% or 95% instead of the 80% value which we previously thought of as standard.

On the question of the method of parallel operation of d-c. generators for power supply to continuous mills, the scheme most generally used today has been developed through a course of evolution. I think one of the first, if not the first, mills to use adjustable voltage control for starting a number of motors was a merchant mill at the Gary Works of the Illinois Steel Company. On that mill we wanted to play very safe and, as close speed control on the mill as a whole was not particularly essential, we applied differential series fields on the generators, compounding them for something like 5% or 6% voltage drop. Of course, that meant that as the load came on the mill the speed of the whole mill dropped a corresponding amount.

This system worked perfectly, but by actual use we found that the differential series field was not necessary and that straight shunt wound generators would operate perfectly satisfactorily in parallel, at any voltage from zero to normal, provided reasonable precautions were taken to insure that they had a slightly drooping voltage characteristic. So today we have a very considerable number of mills of this type in operation with straight shunt wound generators connected in parallel. On one mill we have as many as six such generators in parallel, with all shunt fields in parallel on an excitation bus on which the voltage is controlled by means of a voltage regulator responsive to the voltage on the main 600 volt bus.

The Company with which I am connected uses the system of cross connected differential and cumulative series fields on drives such as reversing blooming mills where it is necessary to have extremely rapid changes in flux in order to get fast acceleration and deceleration, as on such types of drives a slight difference in generator characteristics might give undesirable balance in load.

Mr. Lynn mentioned the use of 3-unit motor-generator sets in order to permit high speed operation of the generators, and consequently decrease the first cost. It is also desirable to use 3-unit sets so as to keep the number of different sets to a minimum in order to keep down the expense for a-c. switchgear, which today, with the large power systems encountered in many mills, becomes quite an item. Some of the mills which are now going in have only two main power motor-generator sets, but the majority of them have three. Most of the larger mills are employing 6000 kw. units, each consisting of two 3000 kw. generators driven by a common synchronous motor.

G. E. Stoltz: Mr. Lynn's paper this morning confines itself to single-purpose motor generator sets or the source of supply of direct current to individual mills, rather than a general mill supply. Naturally where the sets are to be used for one mill, we gravitate to the variable voltage scheme, just as you would on elevators. This naturally eliminates the rotary convertor, due to the greater simplicity in the use of motor generator sets with which starting equipment is not required.

Mr. Winne has mentioned a point that has been coming to our attention recently, and that is a different rating than we have been accustomed to use on synchronous motors. While it is quite possible that plants

that install this type of equipment do not need power factor correction, I think we will still use synchronous motors, due to the fact that they are more efficient and possibly somewhat simpler in design. This will still confine this type of driving unit to the synchronous type, in spite of the fact that we must at times design them for 100 per cent, or possibly 90 per cent, leading power factor and still retain the high pull-out torque that is required on the wide strip mills.

Mr. Lynn has described a number of systems used in causing these machines to properly divide their load. I think in the period of the last ten or fifteen years all of these schemes have been put into practice, and I think in general all have worked out quite satisfactorily. But experience has caused us to gravitate to the one system described by Mr. Lynn, and that is either the use of simple shunt generators, or possibly adding a differential series field which will cause the voltage to droop in case a machine increases its load.

On these large strip mills it is quite essential that the voltage supply to the various motors be kept constant. In the past years I think it has been said that a variation in the supply voltage does not necessarily affect the rolling of the steel, but this is not quite true and is becoming more and more apparent as we are electrifying wider mills and mills having higher delivery speeds. The reason for this is that the inertia of the various individual units driving the separate stands differs and their response to a change in the voltage will be different, so that there may be a tendency to throw a loop or pull metal if the voltage is changed.

With this rather simple design and method of connecting the individual generators to the bus, voltage can be kept constant by the use of a voltage regulator. This makes it possible to tie all or only those generators as will be needed during the rolling period together at no voltage and then build up the exciter voltage with all of them connected together. This obviates the necessity of starting the mill on one set and then paralleling the other sets after the machines have been brought up to voltage, as may be preferable with some of the other methods of paralleling.

Another item of importance in the design of generators for this type of service, and one which differs from the design of generators for ordinary mill service, such as 250 volt power, is that the load on these machines varies over a very wide range. One problem design engineers have always had, and that is a variation in temperature which causes an expansion and contraction of the commutator when load varies over this wide range.

On 250 volt general mill service sets there is a variation of load, but usually this variation does not cover a range much over 50 per cent load. But on these large individual mills the load will vary from 200 per cent load at times to friction load, which is almost zero. This results in a tendency to rapidly raise and lower the temperature of the commutators, with a consequent expansion and contraction of its parts. For this reason we have always felt it important to design these machines with a rather liberal commutator so as to keep the temperature range down and limit the problem of the expansion and contraction.

▲ ▲ ▲ ITEMS OF INTEREST ▲ ▲ ▲

W. Bruce Caldwell has been named works manager of the Calumet Steel Company, recently acquired subsidiary of Borg-Warner Corporation, of Chicago Heights, Illinois.

Mr. Caldwell has been associated with the steel industry since his graduation from the School of Mechanical Engineering of Cornell University in 1912. After graduating from college, he was connected with the National Malleable and Castings Company in Sharon, Pennsylvania until the outbreak of the World War, during which, he served in the Aviation Division of the United States Navy.

Mr. Caldwell was connected with the Sharon Steel Hoop Company of Sharon, Pennsylvania from 1919 until 1933 serving as General Superintendent of all of the plants of that company.

▲

Colonel J. S. Ervin, president of the Mackintosh-Hemphill Company, of Pittsburgh, sailed for England on the Europa, August second, on the invitation of a group of steel men and steel mill builders in Europe, to discuss plans for the use of American-designed machinery in the current expansion of metal-working plants abroad.

Colonel Ervin was accompanied by F. H. Moyer, vice president in charge of engineering, and H. V. Blaxter, chairman of the Mackintosh board.

▲

Alexander L. Feild, consulting engineer for the Rustless Iron Corporation of America and president of the Alloy Research Corporation, has been appointed professor of metallurgy at the Carnegie Institute of Technology. He will assume his new duties in September.

▲

J. M. Hopwood, president, Hagan Corporation, Pittsburgh, Pa., has announced the appointment of Dr. Everett P. Partridge as director of research of Hall Laboratories, Inc. In this position, which he will assume on September 1, Dr. Partridge will be associated with Dr. Ralph E. Hall, the managing director of Hall Laboratories and his staff, with the scientific and technical specialists of Hagan Corporation, The Buromin Company, and Calgon, Inc., all of which are allied organizations, and also with the incumbents of the Industrial Fellowship on Calgonizing sustained by Calgon, Inc., at Mellon Institute of Industrial Research.

▲

At a recent meeting of the stockholders of The

Reliance Electric and Engineering Company J. W. Corey, Sales Manager and S. B. Taylor, Works Manager were elected to the Board of Directors.

▲

Carnegie Steel Company, subsidiary of United States Steel Corporation, announces that it will build a modern wide plate mill at Homestead Works. This is the second step in a program of modernization of mills and other facilities at its various works being carried out by Carnegie Steel Company in line with broad plans which have been under consideration for several years past; the first step being the installation of a continuous hot rolled strip mill now under construction at McDonald, Ohio.

The new Homestead mill will produce plates of standard and special steels, including wide thin plates of "Cor-Ten", the new high tensile steel having a high resistance to corrosion recently brought out by Steel Corporation Subsidiaries and now being used in the new light weight railroad cars and for other purposes. The mill will be capable of producing sheared plates up to 90 inches wide and down to 3/32 inches thick.

Work on the new mill will start at once.

▲

The Clark Controller Company, 1146 East 152nd St., Cleveland, Ohio, have developed and are marketing an entirely new scheme of controlling spot welders.

According to reports—their new control consists of and air operated contactor connected directly to the welder head air cylinder. Being connected in this manner—it operates from the built up or back pressure of the welder cylinder—thereby eliminating the need for any kind of pressure switch, or back pressure relay. The air operated contactor cannot close until the welder points have come together on the work which is to be welded—even though no pressure device is used.

▲

The new continuous cold strip mill which The Youngstown Sheet & Tube Co. is building as an adjunct to its new hot mill is now practically completed and is expected to be put in operation during the next few weeks, it was announced July 6 by Frank Purnell, President of the company.

The new cold mill is a three-stand, four-high continuous mill which will roll up to 72 inches wide, with a capacity of from 150 to 200 tons per 8 hours.

▲

The Pennsylvania Transformer Company, Pittsburgh, Pa., announce the release of a very attractive bulletin entitled "Pennsylvania Heavy Duty Transformers serving the Durable Goods Industries Economically". This circular in a brief way covers a few important facts concerning their Power Transformers-Welding Transformers, and Furnace Transformers.

▲

The Bantam Ball Bearing Company of South Bend, Indiana has been awarded the contract for bearings on the new 26 x 53 x 80″ continuous hot strip mill which is being built for one of the largest steel producers in the midwest and will be located at Gary, Indiana.

The six 4-high finishing stands on this new 80″ mill are being built by Continental Roll and Steel Foundry Company, while the three 4-high stands of the roughing mill will be supplied by the United Engineering and Foundry Company. This new 80″ continuous hot strip mill will incorporate many features of advanced design and is built for high speed production.

▲

Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin announce the availibility of a new leaflet 2202 on the subject "Synchro-Operator".

This new device automatically performs all the functions necessary to synchronize generators so they will operate in parallel.

▲

Crouse-Hinds Company, Syracuse, N. Y., announce the release of a circular concerning its dust-tight panelboards for hazardous locations which are assemblies of one or two pole, 15-ampere, circuit breakers enclosed in heavy sheet steel boxes. They are provided with conduit hubs and one piece, gasketed, covers having flexible circuit breaker operating mechanisms which allow proper engagement of breaker handles when covers are installed.

▲

Changes in the personnel of Duquesne Works of Carnegie Steel Company were announced recently.

Ross L. Leffler, appointed superintendent of personnel. In this capacity he will have general direction of all matters relating to employment, safety, welfare and other employee relations.

Philip G. Fenlon, appointed assistant to the superintendent of personnel, in charge of safety and welfare.

Richard A. Brumbaugh, appointed assistant to the superintendent of personnel, in charge of employment.

Charles C. Hill, Jr., appointed superintendent of blooming mills, roll shop and chipping department.

▲

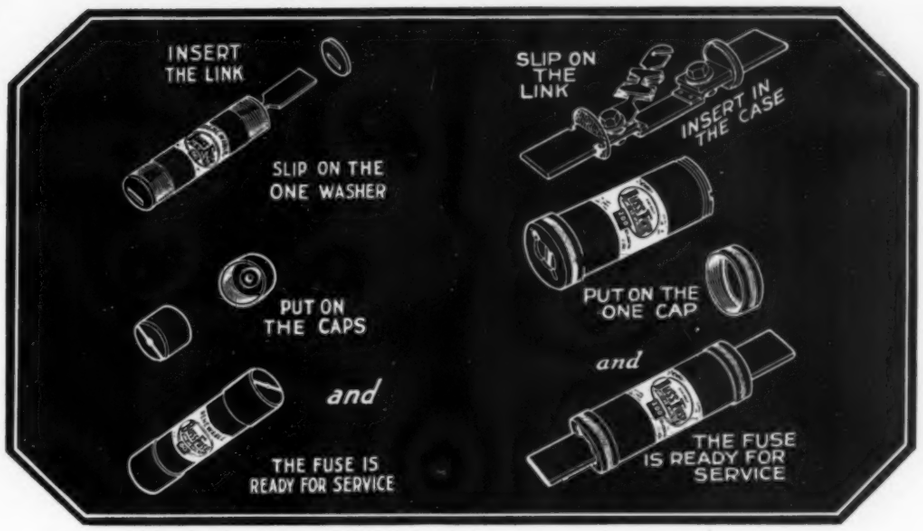
Mathews Conveyor Company, Ellwood City, Pa., announce the publication of a new booklet dealing with the application of conveyors in steel, malleable, and gray iron foundries; brass, bronze and other nonferrous branches of the foundry industry. This fifty page book, supplemented by eighty illustrations, is available upon request.

▲

For installations where their potentiometer control pyrometers are to be used singly, The Foxboro Company, Foxboro, Mass., have developed an improved type of motor drive unit, called the "Type H." This drive comprises a ball bearing enclosed motor and a double worm and gear speed reducing system packed in lubricant.

In addition to its availability for single-controller installations this drive is amply powerful to operate one additional Controller, through a coupling between the Controllers. Although first quality construction is evident throughout the design and construction of this drive, it is offered at a considerable reduction in investment.

A new Bulletin No. 202 gives complete details re-



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BUSS SUPER-LAG FUSES CAN SAVE YOU MONEY

The design of the BUSS fuse case is such that it helps eliminate poor contact. This feature gets right at the heart of most fuse troubles.

It is heat from poor contact that causes fuses to char and burn up—takes the temper out of fuse clips—raises the temperature of the link and causes fuses to open before they should.

Such features as the contact making projection in the cap of the 3 to 60 ampere fuse or the automatic aligning of the terminals of the 70 to 600 ampere fuse are money saving features found exclusively in BUSS fuses.

Of course, BUSS Renewable Fuses have the SUPER-LAG Feature. It gives fuses a time-lag long enough to allow harmless overloads to have a chance to "clear themselves" without causing the fuse to open. It eliminates many needless shutdowns.

These features are just a part of a design in which every detail has been shaped towards preventing fuses opening needlessly.

If You Are Interested In Cutting Costs

Fuses are not "just fuses." It actually costs more money to use some makes of fuses than it does others—but it will cost you nothing to find out why—just drop us a line today.

BUSSMANN MFG. CO., ST. LOUIS, MO.

A Division of the McGraw Electric Co.

BUSS SUPER-LAG FUSES

ADVERTISING PAGES REMOVED

garding Foxboro Potentiometer Controllers and includes a description of this new drive unit for single Controller installations. Copy will be sent on request.

▲

Schweitzer & Conrad, Inc. of Chicago have developed a new line of multi-point contact disconnecting switches. Solid contacts are replaced by series of wire contact fingers,—hard drawn copper wires swedged into a terminal block. Each contact wire has a rolled silver insert which makes silver-to-silver contact with an inlaid silver ribbon in the switch blade. A high percentage of actual contact surface is obtained—and because of the uniform pressure, operation is surprisingly easy even on high ampere ratings. Because there is less friction to overcome between blade and contact original ease of operation is retained. The double blade used is wide which with the ventilation provided for around the contact and hinge end of the switch assure an unusually cool operation and low temperature rise.

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The Aetna-Standard Engineering Company, Youngstown, Ohio, recently acquired from the Jones & Laughlin Steel Corporation, an exclusive license to manufacture and sell a new process and equipment for classifying sheet and tin plate made from continuous strip.

▲

OBITUARIES

After a prolonged illness, Albert Carl Lehman, Chairman of the Board and founder of the original unit of the Blaw-Knox Company, died July 24th. He was in his fifty-seventh year.

ALBERT CARL LEHMAN

His tireless and aggressive efforts in behalf of the company he organized in 1906 as the Blaw Collapsible Steel Centering Company are a matter of common knowledge in the industry. He served the company first as Vice-President, and later as President, continuing in this capacity until recently when he was elected as Chairman of the Board; this office being created by the Board as a mark of appreciation for his efforts in the Company's behalf.

He was a Director of the Blaw-Knox Company and of the following subsidiary and affiliated companies:

Blaw-Knox Construction Co.,
A. W. French & Co.,
Hoboken Land Co.,
Blaw-Knox International Corporation,
Lewis Foundry and Machine Co.,
Pittsburgh Rolls Corp.,
Union Steel Castings Co.,
National Alloy Steel Co.,
Groveton Land Co.,
Blaw-Knox Ltd.,
Milliken Bros. Ltd.,
Compagnie Francaise Blaw-Knox.

Mr. Lehman was also a Director of the Manufacturers Trust Co. of New York and of the Union National Bank of Pittsburgh.

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The association announces with deep regret the death of William H. Powell, electrical engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

A graduate of Cornell University Mr. Powell was associated with the Bullock Mfg. Company, Cincinnati, for eighteen years as manager. In 1908 this company was absorbed by the Allis-Chalmers Company with whom Mr. Powell has been connected for the past 27 years.

Mr. Powell was one of our oldest associate members having joined the society in 1912. We wish to take this opportunity to extend our sympathies to his family and associates.

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ASSOCIATION NOTES

The newly elected officers of the association for the year 1935-1936 are as follows:

President, G. R. Carroll, Electrical Superintendent, Jones & Laughlin Steel Corp., Aliquippa, Pa.
1st Vice President, F. W. Cramer, Superintendent Elect. Const., Republic Steel Corp., Youngstown, Ohio.
2nd Vice President, J. A. Clauss, Chief Engineer, Great Lakes Steel Corp., Ecorse, Mich.
Director at Large, C. A. Kral, Assistant General Manager, Wheeling Steel Corp., Steubenville, Ohio.
Honorary Director, J. Farrington, Electrical Superintendent, Wheeling Steel Corp., Steubenville, Ohio.
Honorary Director, E. Friedlander, Pittsburgh, Pa.
Past President, W. H. Burr, Electrical and Mechanical Superintendent, Lukens Steel Co., Coatesville, Pa.
Past President, W. E. Miller, Electrical and Mechanical Superintendent, Bethlehem Steel Co., Johnstown, Pa.
Treasurer, C. H. Hunt, Assistant to President, Weirton Steel Co., Weirton, W. Va.
Secretary, J. L. Miller, Assistant Chief Engineer, Carnegie Steel Co., Youngstown, Ohio.
Director, C. J. Smith, Superintendent of Auxiliary Depts., Illinois Steel Co., S. Chicago, Ill.
Director, H. G. R. Bennett, Assistant General Superintendent, Carnegie Steel Co., Duquesne, Pa.
Director, Stanley Grand-Girard, Mechanical and Electrical Superintendent, Sharon Steel Hoop Co., Sharon, Pa.
Director, C. R. Tinsley, Electrical and Mechanical Superintendent, United States Pipe & Foundry Co., Bessemer, Ala.
Director, M. J. Conway, Fuel Engineer, Lukens Steel Co., Coatesville, Pa.
Director, C. C. Pecu, Lubrication Engineer, Bethlehem Steel Co., Lackawanna, N. Y.
Director, C. C. Wales, Chief Engineer, Otis Steel Co., Cleveland, Ohio.
Director, L. F. Coffin, Superintendent Mechanical Department, Bethlehem Steel Co., Sparrows Point, Md.
Director, J. A. Voss, Manager, Industrial Relations, Republic Steel Corp., Youngstown, Ohio.

The

CONVENTION ISSUE

containing

Convention papers, abstracts and programs of all the technical sessions

Convention and Exposition Committees

Inspection Trip Schedules

Iron and Steel Exposition Exhibitor Lists

News and Notes on the Convention and Exposition

The ONLY OFFICIAL PUBLICATION covering the 31st Convention and Iron and Steel Exposition of the Association of Iron and Steel Electrical Engineers